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A paper read at a meeting of the American Institute of Electrical Engineers, and the American Electrochemical Society, New York, April 17th, 1903.

RADIOACTIVE SUBSTANCES.

Introduction by President Scott.

We are pleased to have with us as guests this evening the members of the American Electrochemical Society. This Society by its name indicates the intimate connection between two branches of science and of industry. Electricity and chemistry in many of their aspects may have little in common; but the mystery of electricity and the secret of chemical affinity are not far apart. There is an overlapping field in which there is a new science, a new industry and a new society.

The secrets of nature are discovered as individual and usually as isolated facts. These are classified and their generalization results in laws—the laws of nature. This is the field of the scientist. These laws are then applied to direct the forces or mould the materials of nature to accomplish useful purposes. This is the domain of the inventor and the engineer. Scientific and engineering advancement are closely related and their proper equilibrium is essential to advancing civilization. If there be too great generalization from inadequate data or inaccurately observed phenomena; or, on the other hand, if there be meagre ability to apply properly deduced laws to new conditions, the results are of little moment. The notable scientific advancement of the past century has been based upon the fact that men have sought to observe phenomena and obtain definite data before drawing their conclusions instead of speculating upon vague or hypothetical conditions. Along with this development has come also facility in inventing and in applying and utilizing the deductions of science. To illustrate: In the early part of the last

century men were seeking to discover facts to demonstrate the suggested interrelation between electricity and magnetism. Faraday and Henry independently and almost simultaneously determined by experiment that electricity can be produced by magnetism. These facts were amplified by other facts and led to generalizations and laws, and later to dynamos and motors. The dynamo and motor had a very slow development, as it seems to us now. Years were required before the machines began to have an extended application. Later on, developments have been rapid and extensions have been marvelous.

Compare this development reaching over the span of a lifetime with a recent development—that following the announcement of the discovery of the X-ray by Prof. Roentgen. Immediately in laboratories all over the world elaborate experiments and investigations were begun, apparatus was forthcoming for practical use and within a tewlvemonth the X-ray was an important adjunct in many a hospital.

There has been a change in the method of doing things, in the method of scientific observation and of scientific generalization on the one hand, and in the ability of the inventor and the engineer to devlope and utilize the new material which is put at their disposal. We must add to this as a factor in modern development the attitude of the public at large. The scientific observer and the inventor are no longer wizards to be shunned or executed. Science and engineering have done so much in the past that there has come to be a wonderful faith in the future.

Sometimes, it is true, the zeal of the promoter has overweighed the judgment of scientist and engineer, and disappointment has followed the exploitation of schemes which are fundamentally impossible.

It is difficult to foresee the future. Again and again experiments and facts which seem of most trivial consequence have led to far-reaching results in fields least expected.

A simple experiment, the discovery for example, of the relation between electricity and magnetism, is the basis of new systems for the instantaneous transmission of intelligence and the efficient transmission of power.

The discovery of a new property is the opening of a new field of possibility to the scientist, the inventor and the engineer. Hence the value of research. The advanced investigator and the research laboratory are not to be ridiculed if they do not produce full-fledged new methods and new processes superior to

those which have undergone years of development. Fortunate are they if they discover new properties of matter or new relations and combinations which may be the source from which new developments may spring.

On the one hand, we marvel at the advance which has been made in science, invention and engineering. On the other hand, we find that in every direction we have only entered upon the fields of nature which lie before us promising and unexplored. In the production of light and mechanical energy, for example, we are wonderfully in advance of our forefathers, but our present methods are crude and inefficient compared with what we know to be theoretically possible in the transformation of energy, if we had but the means.

It is therefore with a peculiar interest that we direct our attention to an unfamiliar subject; that we learn the wonderful properties of a rare element; that we direct our thoughts to a new field laden with great possibilities.

Stage Setting in the Chapel of the "College of the City of New York" at the time of Mr. William J. Hammer's Lecture before the American Institute of Electrical Engineers and the American Electrochemical Society.

A Lecture delivered at a meeting of the American Institute of Electrical Engineers and the American Electrochemical Society, New York, April 17th 1903.

RADIUM AND OTHER RADIOACTIVE SUBSTANCES WITH A CONSIDERATION OF PHOSPHORESCENT AND FLUORESCENT SUBSTANCES. THE PROPERTIES AND APPLICATIONS OF SELENIUM AND THE TREATMENT OF DISEASE BY THE ULTRA VIOLET LIGHT.

BY WILLIAM J. HAMMER.

The author of this paper has endeavored to exemplify certain fundamental principles connected with the phenomena upon which he has treated; and in considering these subjects, all of which may be said to be on the borderland of science, to bring out by means of experiments, lantern slides and illustrations which accompany the paper, the practical and commercial side. He entertains the hope that the matter herewith submitted will prove of interest to the members of the societies before whom he has the honor of appearing, and may serve in some slight degree to stimulate investigations in these most promising fields.

Fluorescence and Phosphorescence.

Sir George Stokes has given the name of "Fluorescence" to the phenomena which certain substances present in altering the very short waves of ultra-violet light, which are invisible, and transforming them into waves of longer length so that they become visible to our eyes.

In electrical parlance a fluorescent substance might be termed a step-down transformer or perhaps more correctly a frequency changer for light waves. Stokes, as a result of his investigations, framed this law, "When the refrangibility of light is changed by fluorescence it is always lowered and never raised"—in other words, the waves emitted during fluorescence are always longer than those which are absorbed, thus causing fluorescence. There are, in fact, cases where the frequency of

the radiations is increased; but where there is such an exception to Stokes' law some sort of chemical reaction occurs.

The lowering of the frequency of certain ultra-violet radiations, so as to render them visible, was known to Brewster in 1833 and Herschel in 1848, the former terming it internal and the latter surface dispersion; but it was first explained and the name given to it by Stokes in 1852, after a form of fluorspar.

In the case of fluorescence, the emission of the light lasts only so long as the substance is stimulated by the incident beam; but in the case of the phosphorescence, the emission of light continues or persists after the stimulation has ceased, or the original source has been removed. The word phosphorescence is from the Greek " phôsphoros," meaning light bearer.

Prof. E. Wiedemann has suggested the name " luminescence," to cover fluorescence, phosphorescence and phenomena of that character possessed by many substances whose light emissions are unaccompanied by flame or by the temperature of ordinary light waves; but this term can hardly be made to cover the Becqueral rays emitting from radioactive substances.

I have here to-night a collection of tubes containing fluorescent liquids, such as petroleum, quinine, Magdala red, eosine, uranine, saffronine, paviine, æsculine, amidophthalic acid, fluorescine, rhodamin, etc., all of which show most beautiful changes in color when viewed by direct and transmitted light.

I also have some of the fluorescent hydrocarbon " thalleen," prepared by the late Prof. Henry Morton, and some of those most beautiful fluorescent substances, resorcorufin and resorcin blue, for which I am indebted to Dr. Geyer of Steven's Institute. Fluorescent substances are particularly beautiful in the ultra-violet light; for instance: The yellow fluorescene becomes a most beautiful green; the orange colored eosine becomes gamboge; the crimson color of Magdala red a bright scarlet; the straw colored æsculine becomes a pale blue; the transparent and colorless quinine gives its characteristic blue surface tint; the paraffin oil a beautiful blue; and the various other substances giving a beautiful surface color quite different from that of the interior of the solution.

Small pieces of horse-chestnut bark or bark of the ash tree placed in a dilute ammoniacal solution produce a most beautiful fluorescent effect, as the dyeing material descends slowly through the liquid.

Flowers painted with these fluorescent substances on card-

board produce a most beautiful effect when light screened by dark blue or violet glass is thrown upon them.

Sodium vapor fluoresces brilliantly in sunlight.

I also have here samples of tungstate of calcium, platino-barium cyanide, sulphide of zinc, and similar preparations which have been extensively used in the fluorescent screens for X-ray work.

Here is a specimen of Willemite which when exposed to the ultra-violet light produced by the bright snappy condenser spark between these iron electrodes shows a magnificent fluorescence.

Here is a card with words written with a solution of platino-barium cyanide which fluoresces beautifully when exposed to the ultra-violet light of the iron arc, especially when shielded by the accompanying colored glass plates.

I have also one of Prof. R. W. Wood's interesting ultra-violet screens, consting of four isplates of cobalt glass between which are gelatine films containing nitroso-dimethyl-analine with copper oxide, which screen when employed in front of the arc lamp renders beautifully fluorescent a lump of uranium nitrate held in the focus of the invisible rays.

Through the courtesy of Dr. Von Recklinghausen, I am enabled to show you a Cooper-Hewitt tube which is enclosed in a screen soaked in rhodamin, the best substance which thus far has been found which is fluorescent in the light of the mercury arc.

It is well known that many bodies become red hot at a temperature of between four and five hundred degrees Centigrade, and to make them white hot a temperature of between eight hundred and a thousand degrees is necessary; but there are many substances which are phosphorescent and which possess the property of giving off considerable light without sensible heat.

I have here some samples of two phosphorescent substances which have been known for many years—one of them a sulphide of barium or Bolonese phosphorus, and the other a sulphide of calcium or Canton's phosphorus. The former was discovered in 1602 by Casciarlo, a shoemaker in the city of Bologna who prepared it by the partial calcination of a certain powdered heavy spar mixed with a little flour meal, which he roasted in the furnace; and found afterwards that when exposed to sunlight it would shine in the dark. This preparation was succeeded by the discovery of John Canton, who calcined oyster shells with charcoal and meal in a closed crucible, thus producing a brilliant phosphorescent substance called after his name.

Phosphorescence by insolation—or exposure to sunlight—has been extensively investigated by Prof. A. E. Becquerel and Dr. John W. Draper.

Practically all substances in nature are phosphorescent, and although some of them remain phosphorescent for only one ten-thousandth of a second, others retain their phosphorescence for hours.

One may expose sulphide of calcium to sunlight, and after placing it in a dark room for six weeks it will still affect a photograph plate.

Phosphorescence may be stimulated in many ways—by combustion, pounding, rending, friction, by the vibrations from sources of heat, light or electricity; and these various phosphorescent substances are very susceptible to temperature changes.

Various substances also phosphoresce while undergoing crystallization.

I have here a large sheet of cardboard which has been prepared for me by Messrs. Devoe & Company, which is covered with seven coats of Balmain's Luminous Paint or poly-sulphide of calcium, with perhaps a trace of bismuth and mixed with aerated varnish; and it has been put through hot calender rollers. You will note that this phosphoresces most beautifully when excited by burning this piece of magnesium wire before it, or by focusing the arc light upon it. This phosphorescence soon dies out, however; but upon placing my hand against the sheet, the heat of my hand has caused the card to brilliantly phosphoresce. A cold object placed against the cardboard will very much lessen the phosphorescence at that point.

When I place this bust of Franklin between the arc light and the phosphorescent cardboard, you will note I can thus produce a fine silhouette of that distinguished philosopher.

I have prepared for your consideration a number of objects coated with phosphorescent substances. When I burn this piece of magnesium wire in front of this card, or hold it before the arc light, you will note the initials of the A. I. E. E. and the A. E. S., the two societies before which I have the honor of appearing to-night, shine out brightly. I also have a number of incandescent lamp bulbs, coated internally and externally with phosphorescent substances, which you will note give considerable light when stimulated by the burning magnesium; or by turning on the electricity supplying certain of the lamps.

I remember nearly twenty years ago having cut out tiny stars

from cardboard and painted them with luminous paint, and arranged them on the ceiling of my bed room to represent certain of the principal constellations in the heavens. These stars would absorb the light during the day time, and at night would represent an appearance as though the roof had been removed and one was looking at the stars in the sky.

I have here a philosophical toy which I made years ago, with which I can show the varying phases of the moon. I have taken a 25 cent globe, and painted half of it with black Japan, as representing the dark side of the moon which is never seen, the other half I have painted with a number of coats of luminous paint; and by exciting the phosphorescence of this half by the burning magnesium, you will see that by slowly turning the globe around, a perfect representation of the varying phases of the moon occurs.

I hold in my hand here a long tube coated inside with sulphide of calcium, which makes a beautiful wand, which an orchestra leader might use in a dark scene. I remember years ago fixing up a vacuum tube and coil for use as a baton in the dark scene in Gilbert & Sullivan's Opera of Ruddigore, and fearing lest the complaisant leader be some day knocked off his stool by the 8-inch coil.

Here are a couple of postal cards which I secured in Europe showing the Blue Grotto at Capri. They are printed with phosphorescent paints; and on exposing them to the light, you will see they are exceedingly pretty.

Prof. Dewar has shown that egg shells, feathers, ivory and paper become brilliantly phosphorescent if they are cooled to about 200 degrees below zero by use of liquid air, and then exposed to light. Many bodies seem to possess this power of absorbing energy at low temperatures and giving off light at higher temperatures. In fact, Dewar has observed that at a temperature approximately that of the boiling point of oxygen (184° C) all bodies, even living tissues, become phosphorescent.

I have here a collection of forty or more glass tubes containing various phosphorescent substances which, when I burn this magnesium before them, you will note become brilliantly phosphorescent, showing red, yellow, green, blue, and in fact, all the colors of the spectrum. The sulphides of calcium, barium, strontium, zinc, etc., largely enter into their composition. I also have here some fine particles of fluorspar, which, when scattered on this hot plate, glisten like fire flies.

A similar effect may be produced by quinia or its sulphate which when spread on a sheet of paper and laid on a hot metal plate in a dark room, shows a remarkable phosphorescence which develops at the edges and spreads to the centre.

Boracic acid fused and allowed to cool breaks into small pieces, and along the cracks phosphorescent light appears. Potassium sulphide fused with cream of tartar shows the same phenomenon.

Phosphorescent ether may be prepared by digesting phosphorus in ether for some days in a tightly corked bottle, and when a lump of sugar is dipped into this and dropped into a glass of water, the surface appears quite luminous.

The stream of particles, so thoroughly investigated by Prof. Crookes, was given the name of " Cathode rays " by the Germans, as a protest against Crookes' theory of molecular streams propounded by him at the British Association meeting of 1879; Lord Kelvin has told us that the smallest particle which can be observed by the most powerful microscope contains 18 to 20 million atoms, and although until recently the smallest particle we could conceive of was the atom of hydrogen, this being the lightest of gases, Prof. J. J. Thomson has now shown us that these atoms may constitute a thousand fragments, or as he calls them, " corpuscles," and Crookes showed us, and Villard of Paris recently demonstrated conclusively that the Cathode rays consist of a stream of these hydrogen corpuscles negatively charged and moving at a speed approximating 70,000 miles per second; and as illustrating the complexity of an atom, I am reminded by Prof. Hallock that the late Prof. Henry Rowland once said that a Steinway grand piano was a comparatively simple piece of mechanism compared with an iron atom.

Prof. Crookes has shown many notable experiments in which substances have been caused to phosphoresce inside of the Crookes' tube by the molecular bombardment of " Cathode rays "; and I have here some fine Crookes' tubes containing red and white coral, rubies, calcite, lava, etc., which you will note phosphoresce finely. (I am indebted to Messrs. Queen & Co. for certain of these.

Prof. Crookes has made a diamond so phosphorescent inside of a Crookes' tube, as to give a full candle power of light. Rubies emeralds, corals, fluorspar, lime and many other substances similarly phosphoresce in the Crookes' tube.

I have here a Crookes' tube containing calcined sea shells,

which, on connecting to the induction coil, is caused to give off a most brilliant light, and the globe and contents to phosphoresce long after the current is shut off.

Here again I have a tube containing four separately exhausted sections, which are filled with phosphorescent substances, and a tiny tube passing through all of the partitions of the tubes, and being connected with the electrodes at the end. On connecting this to the induction coil a luminous gaseous stream is seen in the tiny tube, and the discharge accompanying it affects powerfully the phosphorescent substances which, you will note, are colored green, yellow, and blue, after the current is shut off.

I have here also a Crookes' " radiometer," the vanes of which are painted with phosphorescent substances, and on connecting the radiometer to the coil the electricity rotates the vanes and causes them to become highly phosphorescent.

At a meeting of the INSTITUTE on January 3, 1902, through the courtesy of Mr. Edison, I was enabled to present some of Mr. Edison's tungstate of calcium lamps which have sometimes been called Edison X-ray lamps. These lamps were Crookes' tubes, the interior walls of which were coated with fused crystals of tungstate of calcium, which were caused to phosphoresce most dazzlingly when they were connected to an induction coil. Through an accident to my large coil, I was unable to show these tubes working as perfectly as I should have liked; and to-night I will show you as an evidence of good faith some of them operating as they should operate, and giving a most powerful light. Incidentally, I am going to show you that this cannot properly be called an X-ray lamp although a form of X-ray tube is employed, as it is not the X-rays outside but the cathode rays inside of the tube which produce the phosphorescence. This tube which I have here and which I have coated with tungstate of calcium and platino-barium-cyanide on the outside, I will now place underneath an ordinary Crookes' tube, that it may be exposed to the X or Roentgen rays; and you will see that while the coated surface fluoresces, as any fluorescent screen will when exposed to Roentgen rays, the moment these rays cease there is absolutely no phosphorescent effect, there being no persistence of the luminescence.

Now, another thing which I think I can show you is that, while cathode rays produce by their action on the interior wall of the glass tube a secondary effect of ether pulsations on the

exterior which are Roentgen or X-rays, I can now produce the converse of this by bombarding the outside of the Edison tube by the Roentgen rays from the Crookes' tube, and you will see then that I have caused cathode rays to be stimulated in the interior of the tube which is merely held near it, causing the tungstate of calcium to become brightly phosphorescent; and you will note that I can deflect the cathode rays with a magnet. I believe this is the first time this conversion of Roentgen rays into cathode rays has been accomplished and is rendered possible by this form of tube.

There are many commercial applications which may be made of this curious property of phosphorescence. Life buoys have been painted that they may be seen when thrown overboard; sheets of cardboard, such as I have shown you, have been used to give light in powder magazines. I have also suggested painting projectiles with luminous paint for use at night; phosphorescent clock and watch dials have been made in large numbers, and it has been suggested to make house numbers, door knobs and escutcheons for key holes of such materials, cover the walls with luminous paper, and even paint the houses with luminous paint.

The taps or keys of incandescent lamp sockets and switches might be made of glass containing phosphorescent material, or the cases painted as I have here done, so that they could readily be seen in the dark; and doubtless certain phosphorescent substances might be used to considerable advantage in connection with various types of vacuum tube lighting and for vacuum tubes used in connection with wireless telegraphy.

I hold in my hand a tiny tube which I secured in Paris, which contains what is perhaps the most brilliant phosphorescent substance that has yet been discovered. It is a special preparation of sulphide of zinc. Here is a second tube containing some of the sulphide of zinc, which also has mixed with it some radium.

A tube of this mixture may be put away in the dark for years, and the radium will act on the zinc, causing it to phosphoresce brilliantly.

Who will say that we shall not some day find a substance which will be so powerfully acted upon by the emanations from radium that it may be used as a source of light?

Here I have a tube which I have made on the suggestion of Prof. Curie, consisting of two bulbs with a stop cock between, in one of which may be placed sulphide of zinc, or similar substances, and in the other radium; and in this manner the radioactivity of various substances may thus be investigated.

A tube containing chloride or bromide of silicon and exhausted to 12 or 15 mm., and sealed, will when rubbed briskly with silk glow in one case a rose color and in the other a greenish yellow.

I hold in my hand here two Geisler tubes, each containing an inner tube with beaded surfaces. In each of the outer tubes is a small amount of quicksilver; and in one tube nitrogen gas, and in the other carbonic acid gas. By shaking these tubes rapidly the friction of the quicksilver against the glass produces electricity, which causes the gas to become luminescent. Various other gases may be thus employed, producing different color effects.

It has been suggested that life buoys could be equipped with a number of mercury tubes, circular or otherwise, and set in different positions, so that the rolling of the buoy in the sea would constantly agitate the mercury and render the tubes luminous.

Here is a tube containing mercurial salts, which changes greatly the color of its phosphorescence by heating the tube in alcohol flame.

In this box I have a large spiral glass tube which is expanded into bulbs at various points throughout its length. This tube, for which I am indebted to my friend Dr. Geyer, contains sulphuric anhydride; and you will note when I connect this to the induction coil and send a discharge of electricity through it that the gas inside of the tube becomes phosphorescent and remains so for a considerable period after the electricity is cut off.

I have here a bottle containing phosphorus and olive oil, which you will see becomes most brilliantly phosphorescent when I withdraw the stopper, and allow the air to enter the bottle. The phosphorescence in this case is due to combustion, or to the oxidation of the liquid. I can also write phosphorescent characters on this ground glass plate wet in hot water with this stick of phorphorus. Other forms of phosphorescence are caused by chemical changes or the slow combustion of decaying vegetable matter or decaying fish.

Occasionally clouds show a phosphorescent light at night; snow is phosphorescent after exposure to sunlight, and no doubt many substances retain during the night the phosphorescent light imparted by the sun's rays during the day.

There are also many insects, such as fire flies and glow worms, and many deep sea fishes which have the properties of producing phosphorescence. Phosphorescence is exhibited among other animals by the infusorian noctiluca, marine radiates, polyps, etc., which are the principal causes of phosphorescence of the sea.

In Fig. 1, is shown an illustration of the "Pyrophorus Noctilucus." This tropical beetle has been most carefully studied by Prof. S. P. Langley and F. W. Very, and the efficiency of the light given off tested by the Langley bolometer; and they have demonstrated that practically all the energy which its phosphorescence represents, appears as light; and the light given off by this insect is the most efficient light known, it being produced at about one four-hundredth part of the cost of the energy which is expended in the candle flame*.

Sir Oliver Lodge says if the secret of the firefly were known, a boy turning a crank could furnish sufficient energy to light an entire electric circuit.

And Prof. Langley says, "There seems to be no reason why we are forbidden to hope that we may yet discover a method (since such a one certainly exists and is in use on the small scale)

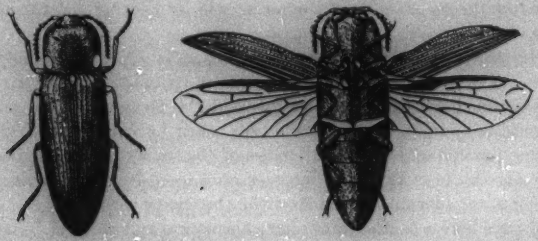

FIG. 1.—"Pyrophorus Noctilucus" (life size), the Producer of the Cheapest Form of Light Known.

of obtaining an enormously greater result than we now do from our present means of producing light."

Langley believes the light of these insects is due to chemical action, as it is decreased by nitrogen which checks combustion, and is increased by oxygen which increases combustion, and furthermore, the product is apparently carbon dioxide.

We also may produce phosphorescence by rubbing crystals together, or by friction of other bodies, or by cleavage, such as fracture of lump sugar in the dark.

Among plants, phosphorescence was first recorded by A. Linnæus, whose daughter discovered it in the nasturtium. Phosphor-

* "On the Cheapest Form of Light," by S. P. Langley and F. W. Very, No. 1258 Smithsonian Misc. Coll.

escence or flashes of light are often observed, especially just after sunset, in the common red and yellow marigold, the tuberose, sunflower, poke weed, martagon-lily and the poppy. The root stock of khus-khus grass and the sap of certain tropical vines and subterranean plants, some liverworts, ferns, mosses, fungi and algæ, and the mycellum of fungi in decaying wood phosphoresce. This phosphorescence is said to be due to slow decay and oxidation, either in the mycelia or fructifications of the fungi. Heat and dryness soon dissipate it.

Having considered certain of the phenomena of phosphorescence and fluorescence, I wish now to call your attention to these remarkable substances which have recently been discovered, which give off light the moment they are created, without having to be stimulated by any form of heat, light, electrical or other vibrations, so far as we are at present cognizant of, and these substances are attracting a great deal of attention, and are likely to teach us more about the constitution of matter, and the co-relation of the vital and physical forces, than any substances which have been created since the world began. I refer to "Radium, Polonium, Actinium and Thorium."

Radium and Other Radioactive Substances.

Prof. Henri Becquerel.
From a portrait presented to the author.

To the discovery of M. Henri Becquerel, member of the Institute, of France in 1896, of those remarkable radiations emanating from uranium, the science, if we may so term it, of radioactivity, owes its foundation

Great importance must, however, be attached to the previous investigations into the phenomena produced on the interior and exterior of vacuum tubes of various kinds by such men as Varley, Hittorf, Crookes, Lenard, Roentgen, Hertz, J. J. Thomson, Goldstein, Schmidt, Ebert, Wiechert, Geissler, Kaufmann, Puluj, Perrin, Villard, Wien, Wiedemann, Majorana, Birkland, Deslandres, Poincaré, Edison, Tesla, Rowland, Michelson

E. Thomson, Moore, Rollins, Campbell-Swinton, and others, which investigations had already wrested from Nature so many secrets bearing upon the constitution of matter and paved the way for the Becquerel rays

Two important links in the chain were supplied by the experiments of M. Henry[1] and M. Niewenglowski[2]. The former showed that phosphorescent sulphide of zinc penetrated black paper and affected a photograph plate, similar to Roentgen rays; and the latter in his experiment replaced the usual cover of a loaded photographic plate holder by a thin sheet of aluminum; on top of this he placed four glass squares sprinkled over with sulphide of calcium rendered phosphorescent by exposure to sunlight. A jeweller's glass bell jar was put over each plate, and the whole apparatus was then placed in a dark room for twenty-three hours. On developing the negative, the plate showed an excellent image of the squares of glass and the bell glass covers which had been made through the aluminum, a substance heretofore supposed to be entirely opaque to light, the white line shown bordering the squares of glass (where the plate had not been affected) indicated that the rays had here been bent or refracted in passing through the edge of the glass, demonstrating that he was only dealing with ordinary light rays.

Subsequently, Prof. Becquerel investigated the effect of phosphorescent substances on photographic plates covered with black paper, such as is used for covering X-ray plates; and which while transparent to X-rays is impervious to ordinary light waves (a plate so protected may be left in the sunlight for twenty-four hours); and he exposed various uranium salts to sunlight to try their effect, at times placing an aluminum, copper or glass plate between the paper and the photograph plate or film. On one occasion after he had placed some double sulphate of uranium and potassium on a photographic plate, the weather became stormy, and he placed his plate with the uranium salts upon it in a drawer, where it remained for several days on account of continuance of the cloudy weather. It then occurred to him to develop the plate; and much to his surprise he found a well-defined impression upon the plate, and this caused without any effect of phosphorescence due to exposure to sunlight. This

1. *Comptes Rendus*, Feb 10, 1896. Vol. cxxii., p. 312.
2. *Ibid*, cxxii., p. 386.

led to his discovery and investigation of the remarkable radiations which have since been known by his name*.

I have here some samples of the first substances employed by Becquerel, consisting of double sulphate of uranium and potassium and double sulphate of uranium and ammonium, for which I am indebted to the courtesy of Dr. C. F. Chandler, of Columbia University

Peligot in 1840 succeeded in isolating metallic uranium from the chloride. Well known forms of it are also uranium arsenate, uranium carbonate, uranium niobate, uranium phosphate, uranium silicate and uranium sulphate. Uranium was first discovered in 1789 by the German chemist Klaproth, he naming it after the planet "Uranus." I have here various forms of this uranium and also some metallic uranium prepared in the electric furnace by Moissan, which is more powerful than any other form of uranium.

Uranium, although widely distributed, is never found in large amounts, and forms several minerals. The commonest of these is "uraninite," commonly known as "pitchblende," which is a compound oxide containing 81½ per cent. of uranium, 4 per cent. of lead and ½ per cent. of iron with oxygen and water, and sometimes magnesia, manganese or silica.

The pitchblende which contains the largest percentage of radioactive material, which has thus far been discovered, is the Bohemian pitchblende. It is also found in Saxony in small pockets, and a distinct vein of it has been found in Cornwall, England. Prof. Curie informed the writer that he had secured some excellent radioactive pitchblende from the United States (Colorado).

The ore as mined in Cornwall yields 18 per cent. to 20 per cent. of the metal, this being the most important source, and this is usually put on the market in the form of uranium sesqui-oxide, and is largely used for giving porcelains a velvety black when heated in the annealing fire, and to some extent for imparting a greenish yellow fluorescence to glass. It has also been suggested to utilize it on account of its high resistance in connection with incandescent lighting.

Following the original discovery of the Becquerel radiations in 1896, came the discovery in 1898 of "Polonium," by Prof. Pierre Curie and Mme. Sklodowska Curie, who in investigating Becquerel

* *Comptes Rendus*, Feb. 24, 1896. Vol. cxxii., p. 420.

radiations from uranium found some samples of pitchblende, from which the uranium is extracted, which was much more powerful than any uranium they had found, being four times the radioactivity of metallic uranium. Concluding naturally that the Becquerel radiations were due to some unknown substance in the pitchblende they commenced a most painstaking search for it, and discovered a substance associated with bismuth, which it resembled very much in its chemical characteristics, to which Mme. Curie gave the name " Polonium," after her native land, Poland.

I have here perhaps the only sample in this country at present of metallic polonium, which in color resembles somewhat the particles of nickel; and here also is some sub-nitrate of polonium.

Where substances are referred to as possessing a certain "radioactivity," for instance 300, it means that the radiations are 300 times as powerful as the original radiations emanating from uranium, which were discovered by Becquerel, and which are taken as a standard of comparison.

The two tubes which I have here to-night are of the sub-nitrate and metallic form, and possess a radio-activity of only about 300. The sub-nitrate form is a white powder, and the metallic, as said, resembles in appearance particles of nickel.

Polonium is precipitated by hydrogen sulphide.

Polonium apparently loses its power much more rapidly than radium; and the Curies have not been able to prepare any in which the rays have been deviable, although Giesel has prepared a form possessing both deviable and non-deviable rays. And Elster states that when polonium is placed in a vacuum, the rays may be deviated by a magnet to a greater extent than those of radium.

Polonium passes more rays through aluminum than do the rays from uranium; but Crookes has shown that they do not penetrate glass, as in the case of radium, and they are readily absorbed by minerals, and readily cut off by thin paper. They are readily absorbed by quartz, fluoride and mica, whereas these substances are freely penetrated by both radium and uranium.

In the same year in which polonium was discovered, those remarkable investigators, M. and Mme. Curie and M. Bemont, succeeded in isolating a second substance found in pitchblende, which was associated with barium and possessed many of the chemical and other characteristics of that substance, and to this they gave the name " Radium." Of this we shall treat later.

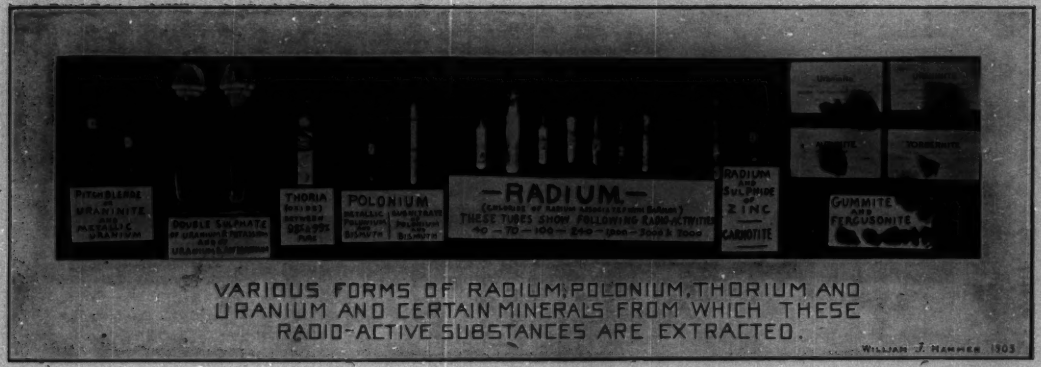
PITCHBLENDE OR URANINITE AND METALLIC URANIUM
DOUBLE SULPHATE OF URANIUM & POTASSIUM AND OF URANIUM & AMMONIUM
THORIA
POLONIUM
—RADIUM—
THESE TUBES SHOW FOLLOWING RADIO-ACTIVITIES
40 — 70 — 100 — 240 — 1000 — 2000 & 3000
RADIUM AND SULPHIDE OF ZINC — CARNOTITE
GUMMITE AND FERGUSONITE
VARIOUS FORMS OF RADIUM, POLONIUM, THORIUM AND URANIUM AND CERTAIN MINERALS FROM WHICH THESE RADIO-ACTIVE SUBSTANCES ARE EXTRACTED.
WILLIAM J. HAMMER 1903

FIG. 2.—Radioactive Substances.

In 1899 was discovered the third substance in pitchblende, which possessed the chemical and other characteristics of thorium with which it was associated, and to this Debierne gave the name "Actinium." It is precipitated by ammonium sulph-hydrate. Crookes states that actinium is identical with the substance which he had isolated from uranium and to which he gave the name "uranium X." The rays from actinium are deviable.

Of the three substances to which I have referred, radium is by far the most important and is of extraordinary interest. It is doubtful whether any substance has been discovered in the history of the world of such stupendous interest and importance and possessing such puzzling characteristics as radium, which seems so at variance with well-established scientific theories as to the constitution of matter.

In Fig. 2 are shown in consecutive order from left to right, a tube containing pitchblende, or uraninite, from which radium, polonium and actinum as well as uranium are extracted; a tube containing metallic uranium made in the electric furnace by Moissan; two flasks containing double sulphate of uranium and potassium, and double sulphate of uranium and ammonium, these being the original salts of uranium with which Becquerel experimented when he discovered the Becquerel rays; a tube containing thorium, the most radioactive substance next to radium; two tubes of polonium and bismuth, one tube of metallic polonium and the other sub-nitrate of polonium; seven tubes of chloride of radium associated with barium ranging in radioactivity from 40 to 7,000; a tube containing radium and phosphorscent sulphide of zinc; and a tube containing carnotite, which, together with the samples shown of uraninite, autunite, torbernite, gummite and fergusonite, are among the mineral substances which are rich in radioactive materials. Other active minerals are orangite, euxenite, broggerite, cleveite, monazite, samarskite, xenotime, æschynite, niobite, arrhenite, hielmite, sipilite, chalcolite, etc.

In Fig. 3 the two tubes of polonium and the seven tubes of radium are shown about two-thirds their natural size.

Radium actinium and polonium, Prof. Curie states, possess an activity which is a million times that of uranium. Prof. Curie says radium emits exactly the same quantity of Becquerel rays when in the liquid air as it does at normal temperature of the atmosphere. The luminosity of the chloride of radium is stronger in the liquid air than in the atmosphere at a normal temperature.

POLONIUM
METALLIC POLONIUM AND BISMUTH
SUB-NITRATE OF POLONIUM AND BISMUTH
—RADIUM.—
(CHLORIDE OF RADIUM ASSOCIATED WITH BARIUM)
THESE TUBES SHOW FOLLOWING RADIO-ACTIVITIES
40 — 70 — 100 — 240 — 1,000 — 3,000 x 7,000
POLONIUM AND RADIUM
WILLIAM J. HAMMER 1903

FIG. 3.—Showing two tubes of Metallic Polonium and Bismuth and Subnitrate of Polonium and Bismuth, and seven tubes of Chloride of Radium and Barium in the possession of the author. (About two-thirds natural size.)

My friend, Mr. R. R. Bowker, whom I met in Paris last Fall, told the writer that he had shortly before that been dining seated between Lord Kelvin and Prof. Becquerel, and that Lord Kelvin had turned to him and said, that the discovery of Becquerel radiations had placed the first question mark against the principle of conservation of energy which had been placed against it since that principle was enunciated.

Within the past month great interest has been attracted by the statement made by Profs. Curie and Laborde that radium maintains its own temperature at 1.5 Centigrade above its surroundings, this being equivalent to stating that half a pound of radium salt would evolve in one hour sufficient heat to equal that caused by the burning of one-third of a cubic foot of hydrogen gas; and that the heat evolved from pure radium salt is sufficient to melt more than its own weight of ice every hour. This evolution of heat, it is claimed, is going on constantly for indefinite periods and leaving the radium at the end of months of activity as potent as it was at the beginning. The problem therefore confronts the world of solving how radium can constantly throw off heat without combustion or without chemical change, as Prof. Curie says it does.

Messrs. Curie and Laborde employed a thermo-electric couple of iron and constantin, one of whose junctions is surrounded by radioactive barium chloride and the other by pure barium chloride. They used two small bulbs of the same dimensions, one containing one gramme of radiferous barium chloride containing about one-sixth of its weight in radium chloride and the other bulb containing one gramme of pure barium chloride.

The junctions of the thermo-electric couple are respectively placed in the center of each bulb, surrounded by the substances. The bulbs are isolated in air within the center of two small identical enclosures, surrounded in turn by a third, which is thermally insulated, and maintains itself at a practically uniform temperature, and under these conditions variations in the surrounding temperature are felt in the same manner at both junctions and do not affect the indications of the couple. Messrs. Curie and Laborde both thus observed a difference of temperature of 1.5 degrees C. between the radiferous barium chloride and the pure barium chloride, the former having the higher temperature. (*Comptes rendus*, March 16, 1903).

In a letter recently received by the author from Prof, Curie bearing upon the question of heat given off by radium Prof. Curie writes as follows: " Since the time I had the honor to see

you at our School of Physics and Chemistry I have continued to investigate into the radioactivity induced by radium and the way that radioactivity is disappearing in the course of time.

"In a study of another kind (in collaboration with M. Laborde) I found that the radium is setting off heat continually and in a very large amount; each gramme of the radium is setting off in each hour 100 small calories, or in other words it is setting off heat enough to melt in each hour its own weight in ice.

"Where is the source of this energy? Both Mme. Curie and myself are not able to go beyond some hypothesis: one of these consists in supposing the atoms of radium evolving and transforming into another simple body and despite the extreme slowness of that transformation which cannot be located during a year; the amount of energy involved in that transformation is tremendous."

The second hypothesis consists in the supposition that radium is capable of capturing and utilizing some radiations of unknown nature which cross the space without our knowledge."

Profs. J. J. Thomson and Rutherford advance the theory that there is a succession of chemical changes going on causing the spontaneous projection of larger masses of material at enormous velocities, and that while certain portions are constantly dying out and becoming inert other portions are constantly increasing in strength and power.

Someone has remarked that for years we have been extracting uranium oxides, and pouring down the waste pipes and into the dust bins the more interesting and precious radioactive substances.

Although radium, polonium and actinium have been termed new elements, in the case of polonium and actinium, they have as yet not been found in sufficiently pure state and in sufficient quantity to give a spectrum, and to prove conclusively that they are new elements. Prof. Curie has, however, stated emphatically that there is now no doubt of radium being a new element.

The tiny brown bulb which I hold in my hand is the duplicate of the one which Prof. Curie showed me at his laboratory last Fall, which contained the only sample of chemically pure radium in the world, this being between two and three one-hundredths of a gramme; and it was the spectrum of that sample, showing only the lines characteristic of radium, as tested by Demarcay, which demonstrated it to be a new element. And with this sample, also, the atomic weight for radium of 225 was determined. The

atomic weight of the barium heretofore always associated with radium, but which in this sample had been eliminated, is but 157.

In answer to my inquiry as to its value, Prof. Curie said that 100,000 francs ($20,000) could not purchase this tiny sample.

I was enabled through the courtesy of Prof. Curie to secure from the Societé Centrale des Produits Chimique of Paris, some nine different preparations of radium and two of polonium, which I have here for your consideration. I was unable to secure any actinium; in fact, but a trace of this substance has thus far been secured.

If the lights are extinguished, and you will sit for a few moments in the dark, I will pass these tubes about the room that you may observe the bright light given off by certain of them. These samples which I have range from forty times the radio-activity of uranium (which is taken as a standard), up to 7,000.

The laboratory, where these substances are prepared, is under the control of Prof. Curie; and up to recent date, all radium of higher radio-activity than 7,000 has been retained for the experiments of M. and Mme. Curie and their associates; but I received a letter recently from Director P. Boulay of the Societé Centrale, in which I was informed that they will shortly put upon the market a preparation of radium, chemically pure or nearly so, at a cost of 30,000 francs ($6,000) per gramme or about $2,721,555.90 per pound.

Radium, while it has been spoken of as a metal, has never been secured in a metallic form, the usual form being as a chloride or bromide.

Prof. Curie told the writer that the result of all the work done in Germany and France in the past three years had only resulted in the securing of about one pound of radium; this including all grades or qualities. Prof. J. J. Thomson says there is far more gold in sea water than there is radium, polonium and actinium in pitchblende.

Prof. Curie took this ring which I have on my hand, which contains a small diamond, into his dark room and holding near it a small pill box containing about a gramme of radium, caused the stone to phosphoresce most beautifully. It was as if a lightened candle had been brought near to it. Prof. Curie remarked that this showed that the stone was a genuine diamond; and if it had been paste there would have been no effect produced, and that radium therefore constituted an excellent means for testing the genuineness of diamonds.

According to M. and Mme. Curie, radium rays act in many ways like light. They reduce silver salts, peroxide of iron and bichromate of potash in presence of organic substances; they also color glass, porcelain and white paper, and they transform greenish yellow platino-cyanide of barium into a brown variety.

Giesel had prepared platino-cyanide of barium with a trace of radium. This spontaneously became brown, and it then polarized light like tourmaline. He also found that this colored rock salt just as cathode rays do, or the vapors of alkaline metals, and furthermore showed that radium salts, brought near the temples or to the closed eyes, produced a sensation of light.

M. Becquerel, referring to the chemical action of radium rays, says that radium and uranium rays act upon silver gelatino-bromide, but produce no effect upon Daguerre plates, or upon photographic papers, and says that colorations of glass, porcelain, paper and certain crystals, as well as the painful physiological effects also belong to this class of phenomena. He also calls attention to the transformation of white into red phosphorus in 24 hours, the reduction of mercuric chloride in the presence of oxalic acid with the precipitation of calomel, and finally the destruction of the germination power of seeds after long exposure.

Becquerel also shows that radium rays possess the same power as the electric spark, or the prolonged action of violet or ultra-violet rays, of restoring the phosphorescent properties under exposure to heat of a body deprived of them by over-heating.

Practically all the radium which has thus far reached this country, with the exception of that in the possession of the author, has been the German radium, and Prof. Curie tells the writer that he had tested all of the German productions, and he has found none of them to exceed a radioactivity of 300.

De Haen of Seelze near Hanover, Germany, and Giesel, of Brunswick, also have manufactured radium. De Haen recently informed the writer that the preparations he puts on the market cost ten and thirty shillings per gramme.

As indicative of the enormous difficulties to be encountered in procuring this wonderful substance, it is interesting to note that it takes 5,000 tons of uranium residues to produce a kilo (2.2 pounds) of radium; and the cost of handling these residues is $2,000 per ton. To secure the chemically pure radium is enormously expensive, and it would be impossible to do this by chemical analysis, therefore the far more sensitive electrical method is employed, and the Curies say that they can detect the presence

of a radioactive substance by the means of such a minute quantity that it would require 5,000 times this amount to show at all in the spectroscope. And it is stated that this method of electrical analysis is thousands of times more sensitive than spectrum analysis and millions of times more sensitive than chemical analysis.

In Fig. 4 is shown the "electrometer" method with which the Curies have studied the radioactivity of different substances. It consists of two plates, A and B, on the latter of which is placed the radioactive substance to be tested. This makes the air a conductor of electricity between the two plates, and for measuring this degree of conductibility, the plate B is brought to a high potential by connecting it to one side of the storage battery P, the

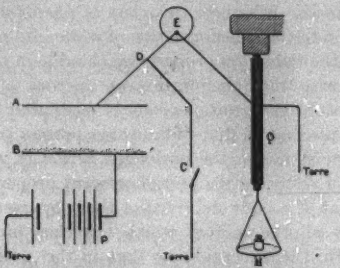

FIG. 4.—Apparatus employed by M. and Mme. Curie in the study of radioactivity.

other side of which is connected to the ground. If the plate A is brought to the potential of the ground by the wire C-D, an electric current begins to flow between the two plates, A and B. The potential of plate A is shown by the electrometer E. If we cut this communication with the ground at C, the plate A becomes charged causing the electrometer to deviate. The speed deviation is proportionate to the intensity of the current and can serve for measuring it. But it is preferable to make this measurement by compensating the charge taken by plate A, so that the electrometer remains at zero. The charges which are extremely feeble can be compensated by means of a Piezo-electric quartz Q,

one armature of which is connected with the plate A, and the other armature grounded. The quartz plate is given a certain tension by weights placed on the plate H. This tension is gradually produced and gives a charge of a definite quantity of electricity which can be measured. The operation may be so regulated that there is a constant compensation between the quantity of electricity which passes through the condenser and that of the opposite sign furnished by the quartz. So we can measure in an absolute value the quantity of electricity passing through the condenser in a certain time.

Doubtless some loss is caused by the rays which pass directly through the condenser plates.

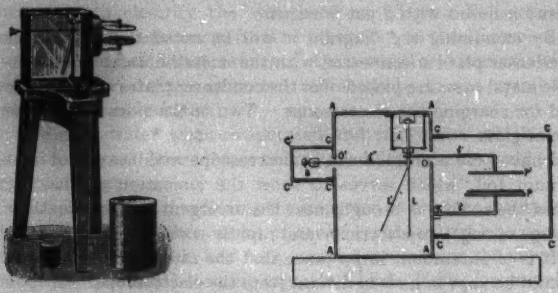

FIG. 5.—Curie's Electroscope for the study of Radio-activity

Dolezalek has designed a very sensitive type of electrometer built by Bartels of Göttingen, a description of which may be found in *Verk, der Deutsche Physik Ges., iii* (1901).

It is well known that the leaves of a gold or aluminum foil electroscope will hold their charge in dry air indefinitely; but the Becquerel rays are found to dissipate the charge by ionization of the air, or rendering the air a conductor of electricity (the electroscope may also be discharged by Roentgen rays, cathode rays and ultra-violet light).

In Fig. 5 is show a form of electroscope devised by the Curies for the study of radioactive substances. Referring to the diagram to the right, it will be noted that the electroscope consists of a single movable sheet of gold or aluminum foil attached to a stationary sheet of copper L, being supported by the insulating

piece I. The radioactive substance to be tested is placed on the lower of the disks P and P′, preferably on a removable plate. The radiations make the air a conductor between these two plates The electroscope is charged by means of a stick of ebonite rubbed briskly and placed near the rod B. This deflects the sheet L′, from the vertical and it so remains for a very long time. When radioactive substances are brought near it, the gold or aluminum leaf is caused to lose its charge, and the leakage is observed by means of a stationary telescope shown in the left hand figure, which is provided with a micrometer scale. The time taken for the discharge of the electroscope is taken by means of a chronometer or watch. By suitable lighting, the front edge of the foil may be made to appear as a very fine line, and its position noted with great precision.

By examining the diagram it will be noted that the upper condenser plate is connected with the metallic case. Detachable metal cases are placed over the condenser plates and over the rod for charging the electroscope. Two of the sides of the case are of glass.

I have here a simple form of electroscope with leaves of aluminum foil, which serves to show the ionization of the air; when the radium is brought near the divergent leaves lose their charge of negative electricity and rapidly come together.

It is of paramount importance that the radioactive substance should be kept in a room distant from the electroscope.

At the present moment the clothes of every person in this room and all the walls of the room are radioactive by reason of the presence of the nine preparations of radium which I have here this evening.

Prof. Curie told the writer that it was often impossible for him to go near his instruments to make any measurements for hours, after being in the proximity of some radium, and those who have worked with this substance have found the greatest difficulty in keeping their tools and instruments and themselves free from the radioactivity imparted by the radium. The energy represented by radium is something enormous.

Elster and Geitel* have shown that a fine wire of any metal placed in the atmosphere and charged negatively from some source of current, say of 500 volts, causes the wire itself to become radioactive, and this radioactivity may be scraped off

* *Phys Zeit.*, 1901, ii., p. 590

and will affect photograph plates, ionize the air, etc. It cannot, however, be washed off. It is stated that lightning rods and even the leaves of trees all become radioactive and it has been shown that falling rain and snow are for a time quite powerfully radioactive; and after they have fallen, a wire negatively electrified in the atmosphere has only a small amount of radioactivity, apparently showing that the rain and snow have carried the radioactive particles in the atmosphere down to the ground.

McLennan has made experiments with the negatively charged wire in Montreal and subsequently at the foot of Niagara Falls; and has found the result about one-sixth as powerful in the latter place as in the former; and he has also shown that it was not necessary to electrify the wire used at Niagara Falls, as it received a sufficient charge from the electricity in the atmosphere.

McLennan found that rain caught in a vessel and immediately evaporated to dryness imparted radioactivity to the vessel in which it was evaporated.

Ordinary water when evaporated and rain water which has stood for several hours before being boiled down do not yield any radioactivity.

As an evidence of radioactivity imparted to another substance by radium, I have here some pieces of cardboard which constituted the box which held my samples of radium for several months. The box becoming injured, I broke it up, fortunately saving the pieces; and six days after the radium had been removed, I looked up the pieces and was surprised to find them luminous in the dark. Subsequently I tried their effect on a photograph plate; but did not succeed in getting any impression. Three weeks later it occurred to me to try and stimulate the radioactivity of the cardboard, which had not been near radium for over a month, by burning magnesium wire, when I found I could make the cardboard brighter than it had been in the first place. I have also stimulated the radioactivity by sparks from a coil, especially when producing ultra-violet rays, by using a condenser bridged across the secondary and employing pure iron electrodes. I tried the burning magnesium with various samples of cardboard which had not been exposed to the radium, and there was no phosphorescence. It has already been stated that various substances which become radioactive retain that property for a short time only, and it is interesting to note its retention for such a long period of time and to note this

ability to stimulate and make visible the imparted radioactivity.

This experiment suggests the discovery made by Prof. E. Wiedemann that a mixture of sulphide of calcium with a little sulphate of manganese is not altered when exposed to cathode rays; but some time after its exposure it bursts into a vivid greenish glow when slightly heated; and to this phenomenon he has given the name " thermo-luminescence."

Prof. S. P. Thompson also showed that fluorspar which by prolonged heating has lost its luminescing power, regains the power of thermo-luminescence on exposure to Roentgen rays when reheated.

Prof. Trowbridge also finds that this restoration is also effected by exposure to the electric glow discharge, but not by exposure to ultra-violet light.

It is also stated that an object coated with calcium sulphide and exposed to the sunlight will phosphoresce about ten hours; and even after it has lost its luminosity, it can be caused to again give light by heating first by the hand, then over a water bath, and finally on a hot stove.

McLennan has found a very large number of salts are brought into a condition by cathode rays, in which warming makes them radioactive for a short time, the supply of negatively charged particles discharged from the surface coming to an end.

Prof. Rutherford of Montreal, who has given a great deal of attention to radioactive substances, particularly to investigations into thorium, which next to radium is the most radioactive substance yet discovered, has found that by electrifying a wire negatively with a current of 500 volts connecting the positive pole to the ground; and by connecting a sample of thorium to the earth, that the thorium particles were attracted to the negatively charged wire, producing a greater radio-activity than he had ever found in any thorium preparation which he had made.

I have here a sample of oxide of thorium, the radioactivity of which was discovered independently by Schmidt and Curie. This sample is between 98 and 99 per cent. purity. From this body Prof. Rutherford has isolated a substance which he calls " ThX;" and extraordinary as it may seem, it has been found after separation of the active constituents represented by the ThX from the thorium, that the ThX loses its radioactivity, and this is taken up by the thorium in exactly the amount which the other loses.

Sir William Crookes has also separated a non-uranium residue

from uranium, leaving the latter without radioactivity. Whilst the whole of the radioactivity has been concentrated in the residue to which the name UrX was given, Crookes, as already stated, claims that Actinium is but another name for his UrX.

The only case of radioactivity induced by cathode rays in a neutral substance has been that of bismuth, discovered by Villari.

Prof. Curie has discovered that radioactive gas emanates from radium, and Rutherford has discovered the gaseous emanations from thorium, Messrs. Rutherford and Soddy have investigated extensively these emanations, and they have succeeded in condensing them at the temperature of liquid air. A preliminary account appears in the proceedings of the Chemical Society of London for December, and Prof. Rutherford writes me that the full paper will shortly appear in the Philosophical Magazine; and he states furthermore that in his opinion this proves beyond doubt the gaseous nature of the emanations.

The serious physiological effects of radium are well known, and Messrs. Giesel, Becquerel, the Curies and others, have given important evidence thereof. As stated in the appendix of a paper read by the writer at the 159th meeting of the INSTITUTE on January 3, 1902, dealing with the subject of radioactivity, Prof. Curie told the writer that he would not care to trust himself in a room with a kilo of pure radium, as it would burn all the skin off his body, destroy his eyesight and probably kill him. The writer felt the effects for weeks of a slight burn from inadvertently carrying a wooden box containing eight tiny sealed glass tubes of radium under his arm for several hours.

Mr. W. E. Hidden has called the attention of the writer to some phenomena which he has observed in a mine in Barringer's Hill, Llano County, Texas, which mine contains yttrium, thorium and uranium. Pockets of ore have been found, ranging from a few ounces up to a capacity of 70 kilos, which were the nuclei or focal points of rigid lines radiating in every possible direction. These lines penetrating great masses of quartz and orthoclase feldspar, and gigantic pegmatyt, to distance often of several feet, in some cases of from five to eight feet, he has observed that these radial lines were fissures and bore no relation to the natural cleavage or the crystalline form of the huge rock masses in which they existed. Easy parting took place along these radial lines, making the ore quickly available.

It is Mr. Hidden's theory that, as these lines directed to ores

rich in uranium and thorium, both well known sources of radium, etc., the phenomenon is due to an electric or other effect of radio-activity; it being untenable, he believes, to explain this phenomenon on the basis of expansion or contraction.

The slide which I will show on the screen shows clearly a pocket of ore with the lines radiating therefrom in all directions.

Eighteen years ago, while in Italy, the author visited the celebrated aquarium in Naples, which is probably the finest in the world; and while there was enabled to test the shocking abilities of the Electric Ray, or " Torpedo Galvani " and was astonished at the tremendous shock which he received; and in this connection, it is interesting to call attention to the fact that there are fifty or more fishes which are known to possess this property of giving powerful shocks. The " Gymnotus " or Electric Eel, and the " Torpedo Galvani " or Electric Ray being the best known of these.

It will be recollected that Faraday drew a powerful spark from a Gymnotus at the Polytechnicum, London, and he estimated the shock to be equivalent to that given by a battery of leyden jars of 3,500 square inches of surface. And many writers have referred to the ability of these electric fishes to give powerful shock for a long period of time. D'Arsonval has caused them to light incandescent lamps and they have been known to magnetize needles and decompose water by the electricity they produce. These fishes doubtless using this faculty as a means of defence and also for procuring food. My object in mentioning this is to state that last Fall I again visited Naples and thinking that perhaps an electric torpedo was on exhibition, it occurred to me to take with me some half dozen tubes of radium which I had in my bag, and see whether the radium had any effect upon the power of the fish to give powerful shocks. The fish, as at the time of my previous visit, was lying in a shallow wooden box containing wet sand and a small amount of water. By taking hold of the side of the fish and pressing with the thumb on one side and the fingers on the other, or by either pinching or tapping the fish, the cells with which the fish was equipped discharged themselves and gave a shock sufficient to twist one's arm very badly. After the members of our party had each received a shock, and as soon as a few persons present had gone away, I laid the six tubes of radium on the fish (which is shaped very much like a flounder), leaving them there for about twenty minutes. I then replaced the tubes in the box, and taking hold

of the fish tried for fifteen minutes to get it to give me a shock by tapping or pinching in the same manner as previously done when the fish gave off shocks, and without receiving the slightest shock. Now, I am prepared to admit that the fish might have been "entirely out of shocks"; still, it is well known that these fishes will continue to give out shocks for a very long period of time, one authority reporting 360 shocks in seven minutes' time; but after exposing the fish to the radium, I could get absolutely no manifestation; and in this connection, it is to be remembered that the physiological effects of radium, such as burning, destroying microbic life, producing the sensation of light when a tube is held against the closed eye or temples (which is doubtless largely due to the phosphorescence of the pupil of the eye, but which may also affect the nerve centers), and also the electrical effects, where charged bodies are caused to give off their charge by the ionization of the air; and one must also remember the very numerous chemical effects and the destruction of the germinating power of seeds, the changing of oxygen into ozone, and various other phenomena of radium which would lead one to wonder whether the radium did not affect the ability of the fish to give off electric shocks, perhaps producing a partial paralysis.

The experiment is of some interest, and may be perhaps repeated by others who have better facilities than I to continue the investigation. I have sometimes wondered how that fish was getting along in Naples; though I believe the waters of the Mediterranean abound in them.

Note—Since writing the above description of his own experiments, the writer has learned of the recent experiments conducted by Prof. Curie, in which a few milligrams of radium introduced beneath the skin of a mouse near the vertebral column produced death by paralysis in three hours; and tubes of radium placed in contact with the back of the necks of guinea pigs have killed or paralyzed these animals in a few hours, according to the length of exposure to its fatal radiations.

As illustrating the action of radium rays upon bacteria, E. Aschkinass and W. Caspari speak of exposing cultures of *micrococus prodigiosus* to a radium preparation, and state that the rays killed the germs very effectively in about three hours.

The work of Rutherford, the Curies, Becquerel and others has demonstrated that there are three entirely distinct types of rays emanating from radium (Rutherford having first pointed out that uranium possessed two separate types of rays, "α" and "β."

the former easily absorbed even by gases, whilst the latter are very penetrating and but little absorbed by gas). Those which constitute by far the most important class are the "α" rays. They constitute the major proportion of the rays, and are those which produce the greatest portion of the ionization of the gas, which has been observed under experimental conditions.

These "α" rays possess in common certain characteristics of Roentgen rays, and by many have been thought to be Roentgen rays. I shall call your attention later to certain effects which are identical with those produced by Roentgen or X-rays. They have been considered absolutely non-deviable, as X-rays have been held to be.

Rutherford has, however, recently shown that in a very powerful magnetic field he could deflect about 30 per cent. of the rays, and in experiments now being conducted with a strong electric field, he has been able to deflect about 45 per cent. of the "α" rays. The "α" rays are readily absorbed, and a thin screen of metal will serve to cut off the greater portion of them.

In this connection I would state that Mr. Tesla informed the writer recently of an experiment he had made in which he had succeeded in deflecting the X-rays themselves, and M. Blondelot has recently claimed as the result of his experiments that X-rays are susceptible of polarization. If this is so, it is argued they may be shown to be ordinary light waves of extremely short wave length.

Strutt and Crookes have suggested that the "α" rays consist of positively electrified particles, and this view Rutherford supports, calling attention to the fact that they possess characteristics similar to the "Canal Strahlen" of Goldstein. These Goldstein rays have been shown by Wien to be positively charged particles, moving at high velocities.

Rutherford, as a result of his most recent observations, considers that the "α" rays move at much higher velocity than the Goldstein rays; and he estimates that the energy of the "α" rays is a thousand times greater than that of the "β" rays.

Rutherford says all the radioactive substances, including polonium, as well as excited bodies and the emanations, give out "α" rays.

The "β" rays are much more penetrative and much longer, and in every particular correspond to the characteristics of cathode rays. They are readily deflected by a magnet. They

discharge electrified bodies by ionization of the air, affect photograph plates, etc.

M. Villard, in 1899, proved that the cathode rays are negatively electrified corpuscles or fragments of atomic hydrogen, and these corpuscles, as they were named by J. J. Thomson, which he has shown to be one one-thousandth of the mass of the hydrogen atom, are projected from the cathode at a speed approximating 70,000 miles per second.

The "γ" rays are the rays possessing the greatest penetrative effect. They will excite or produce radioactivity through the air at a distance of three or four feet or more.

Some recent experiments made by Rutherford show the relative penetration of the three classes of rays through aluminum sheets of varying thicknesses, before a loss is observed of half of the intensity, and this shows for the

"α" rays a thickness of aluminum of .0005 cm.
"β" rays a thickness of aluminum of .05 cm.
"γ" rays a thickness of aluminum of 8. cm.

Mr. Rutherford, who has conducted most painstaking investigations into the penetrative character of the radiations from uranium, radium, thorium, etc., recently wrote the author in answer to some questions on the subject, that he had found that the radium rays were reduced to half value after passing through 1 cm. of lead, 1 inch of iron and about 8 inches of water, the radiation being reduced to about 1 per cent. of its original value, after passing through 7 cm. of lead, 7 inches of iron and 56 inches of water.

In the lantern slide thrown on the screen is an interesting illustration of the effect of magnetism on the deflectable rays from radium. There are four large steel magnets, two being placed opposed to each other, and the other two so that unlike poles are opposite to each other, making a strong field of force between the two magnets. I have placed six tubes of radium a short distance above the magnets and in a line running across and between the poles of the two pairs of magnets. It will be seen that the magnetic rays in the case of one pair of magnets have repelled the radium rays so that the negative is but slightly affected. Whereas, in the case of the other pair of magnets the radium rays have been attracted by the magnets affecting considerably the negative around the pole pieces.

Prof. Curie states that half of the induced radioactivity, when exposed to the air, is lost in certain substances in half an hour;

but in a closed vessel, where the air has been made radioactive, however, this radioactivity has not lost half of its strength, even after four days' time.

It is desirable to keep radium free from moisture, preferably in sealed glass tubes. It readily takes up moisture, and then soon loses its luminosity, which may, however, be regained by dissolving and precipitating the substance and thoroughly drying it. The luminosity may also be considerably heightened by subjecting the radium to high temperatures.

Polonium like uranium does not possess the power of exciting radioactivity, as it does not give off any emanations; whereas, in the case of radium and thorium, there is an actual emanation, producing radioactivity in surrounding objects by the deposit of radioactive matter.

When one considers the remarkable effects produced by radium it would almost seem that it is matter tearing itself into tiny pieces, and projecting these infinitesimally small particles through all matter at a speed from half to even the full speed of light, and rendering all substances about it radioactive, and still without appreciable loss in weight in the original substance, and without disparagement of the accepted wave theory of light one naturally "harks back" to Newton's corpuscular theory of light.

While various theories have been advanced to account for the phenomena of radium, there remain many things which have not been satisfactorily accounted for; and perhaps the subject which has been most widely discussed is the loss in weight of radioactive substances.

At the British Association meeting last summer, Prof. J. J. Thomson is reported to have stated that if a square centimeter of surface were covered with pure radium, it would only lose in weight one thousandth of a milligram in a million years. This is in accordance with the previous statements made by Becquerel.

Later in the year, A. Heydweiller, of the Royal University, Munster, Germany, stated that he had been testing a sample of De Haen's preparation of radium, and found that it lost in weight two one-hundredths of a milligram per day for fifty days, and a whole milligram in that period. (*Phys. Zeit*, Oct. 15, 1902.)

The great discrepancy in the statements on this important subject, led the writer to enter into correspondence with Profs. J. J. Thomson, Henri Becquerel, Lord Kelvin, Sir William Crookes, P. Curie and A. Heydweiller, which resulted in the following expression of views.

Prof. Thomson was inclined to think that from the magnitude of loss found by Heydweiller, it must be due to some secondary effect, and he stated that he could not speak with certainty without a greater knowledge of the details of the experiments. As accounting for the results he, however, drew attention to the well-known coloration of glass by radium, by remarking, "One point, however, that ought to be attended to in these experiments is the effect of the radiation from radium on glass. Glass, as is well known, gets deeply colored when in contact with radium. It seems to me possible that the glass might be charged right through. If this were the case, it is possible that reactions might occur between the glass and the air, producing volatile substances and a loss of weight. I only throw this out with hesitation, for as I said before, I am not familiar with the details of the experiments."

Prof. Becquerel informed the writer that he knew nothing reliable regarding the experiments of Heydweiller, and called attention to his original paper on this subject which appeared in the *Comptes rendus* of March 26, 1900, adding, "I believe I am the first to have published an estimate in this way which could only result from my own experiments. The loss of one milligram per square centimeter requires one thousand million years. This statement refers only to the part of the deviable portion of the radiation to which measurements were applied; but this is only a part of the total loss. The deviable radiations comprise rays ranging from 10^{9} and 3.10^{10} c.m Besides, there is also all the non-deviable portion, either penetrating or absorbing, which corresponds to a notable loss of energy; and in addition, if the emanation is of material importance, which seems quite probable, the loss on this account would be a thousand times greater. These estimates are but theoretical, for it is probable that at least a portion of the mass calculated or estimated as material is apparent and corresponds to the effects of induction."

In response to an expression of view from Sir William Crookes on a theory to satisfactorily account for the phenomena of radioactive substances, he wrote as follows: "You will find them fully given in my address to the British Association at their Bristol meeting in 1898. I have not seen any special reason to alter the views there propounded"; and in writing on the subject of Heydweiller's experiments, Prof. Crookes says, "I do not think the experiments of Heydweiller have been corroborated by other observers; and there are many sources of error in his

experiments which I should like to see discussed before giving credence to it. Personally, I find no loss of weight in a rich sample of radium compound during continuous weighings extending over many months. I should be inclined to agree with Becquerel and J. J. Thomson."

Lord Kelvin wrote that he was sorry not to have been able to make any experiments on radioactive substances which could allow him to offer any opinion that would be helpful on the subject, and added, "What you tell me regarding radium and your correspondence with Prof. J. J. Thomson is very interesting."

On this point Prof. Curie recently wrote me as follows: "I never did believe in the exactness of Mr. Heydweiller's experiments; and I always thought he did not take care enough to avoid some source of errors. In fact, with a substance considerably stronger than his own I only obtained a reduction in weight of 1-10 of a milligram in four months for several decigrams of substance, and as the tubes were used at the same time in several experiments, that loss of weight does not allow me to affirm that radium is losing weight spontaneously. I believe, meanwhile, as does Mr. Heydweiller, that the question cannot be answered in any other than an experimental way, and that all speculative theories are of small interest. I have published my recent researches in the *Comptes Rendus de l'Acadamie des Sciences de Paris*."

As regards the published statements of Prof. Heydweiller's experiments, the writer can state that he is most reliably informed that a mishap occurred during his experiments which resulted in one of the tubes becoming cracked, which was not observed until later; and that this practically nullified the results published; and, in fact, they have not been confirmed by subsequent tests; but, on the other hand, they tend to corroborate the experiments of Becquerel and the statements made by him, Sir William Crookes, J. J. Thomson and others. The writer is also informed that Prof. Heydweiller is continuing further experiments, the results of which will doubtless be published when his investigations are complete.

As bearing upon the coloration of glass already referred to, I hold in my hand a flask which I secured at the laboratory in Paris, which has contained radium, and has been most beautifully colored a deep violet. I also have several tubes in which radium has been kept, which are similarly colored, and in this connection I would call attention to the fact that X-ray tubes which have

been in use for a considerable time become similarly colored, forming another link between the Roentgen rays and radium rays.

I also have here a tiny bulb of glass which is colored a deep brown. I have seen only one other piece of glass colored in this way, this being due to the difference in the chemical constituents of the glass (though in some cases the glass subsequently turns a violet color). This is a duplicate of the tiny tube which Prof. Curie showed the writer, which contained between two and three one-hundredths of a gramme of chemically pure radium.

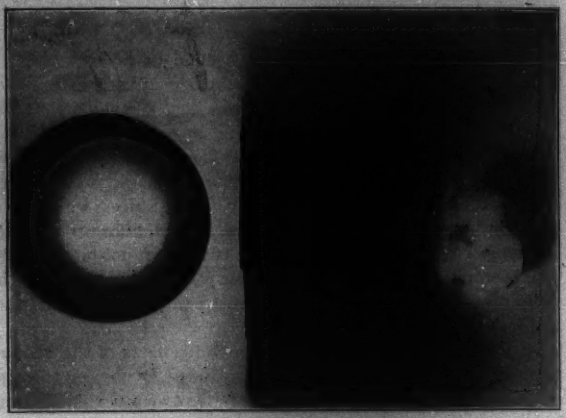

FIG. 6.—Radiograph Made by Radium of a Disc for Testing Radioactivity, a Block of Rock-salt and a Lump of Pitch-blende.

It is interesting to note that the Becquerel rays induce activity which persists, whereas that excited by Roentgen rays ceases immediately on the removal of the rays.

As illustrating the X-ray character of radium rays I would call your attention to Fig. 6, in the center of which is shown a block of rock salt. The original sample was about one inch thick, and was so transparent that a person's features might be seen through it. The rock salt is not only transparent to ordinary light, but also to ultra-violet light, whereas it is very opaque to X-rays.

Mrs. Hammer, appreciating the series physiological effects of radium, has made the interesting suggestion that radium be kept in boxes made of rock salt; and the author is now having such a receptacle made. This might be even more satisfactory than a lead box. It would be interesting to note the change in the temperature of such a box or vial which so well intercepts the Radium rays.

The illustration referred to was made by placing the rock salt on a photograph plate with the radium some 5 inches above it.

To the right of the rock salt is shown a piece of uraninite (pitchblende), from which radium is extracted; and you will note that not only has the mineral been photographed by the radium above it, but the radium has acted on the radioactive constituents of the pitchblende and caused this to affect the plate.

The disk shown at the left of the cut is one made in Paris for the examination of radioactive substances. I have one of these here, and it consists of a rim of brass, enclosing a brass washer with a glass disk at the center. The opposite face is covered with aluminum foil, and between the aluminum and the glass is placed some radium of 1,000 radioactivity. Substances which it is desired to examine are laid on this disk. It is, however, a rather crude piece of apparatus; but in the cut shown not only has the disk been photographed by the radium 5 inches above it, but the radium inside of the disk has penetrated through the aluminum and fogged the plate.

In Fig. 7 are shown some interesting effects of the radium rays in affecting a photograph negative after passing through lenses. The lenses "A" and "B" are plano-convex condensing lenses, one being placed with the flat surface down, and the other with the convex surface down. "C" is a double convex lens of crystal, "D" is a plano-convex lens of uranium glass and "E" represents an ordinary glass prism.

It is stated that radium rays cannot be reflected, refracted or polarized. Those familiar with the phenomena of light will, I feel sure, be interested in the above photograph.

In Fig. 8 is shown another illustration of the penetrative character of the rays, it being a thick lead box containing six tubes of radium, ranging from a radioactivity of 40 to 7,000; this box being laid upon a large steel magnet ¾ of an inch thick. You will note the degree of penetration of both the lead and the steel varies according to the radioactivity of the radium in the various tubes. The exposure was made in twenty-two hours.

FIG. 7. Radiographs of Various Types of Lenses Made by Radium.

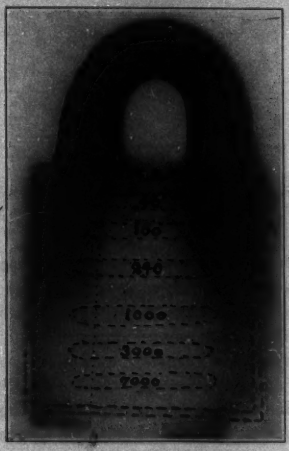

FIG. 8.—Radiograph showing Degrees of Penetration of a thick sheet of Lead and a Steel Magnet by Tubes of Radium of Different Radioactivities.

Fig. 9 illustrates the penetration of the rays through black paper, the steel tool shown having been laid on the plate covered with two thicknesses of heavy black paper, such as used for

FIG 9.—Radiograph of Steel Tool made by Radium Acting Through Two Thick X-ray Plate Envelopes.

wrapping X-ray plates; a single sheet of which is entirely impervious to light. The exposure was made in twenty-four hours.

Fig. 10 shows a mouse which was radiographed in twenty-four hours by laying it directly on a plate, which was, as in the case of

FIG. 10.—Radiograph of a Mouse Made by Radium in Twenty-four Hours.

other experiments, placed in the bottom of a trunk, the trays being replaced and the trunk wrapped in three thick rugs, and kept in a dark room for twenty-four hours.

The radiograph of the mouse shown in Fig. 11 represents a mouse caught on another occasion, in which I placed the mouse, trap and all on the plate, leaving it there for three days. The trap was an ordinary 6 cent trap; and it will be noted that the metal parts of the trap are shown opaque, whereas the portion of the wood nearest to the radium is shown absolutely transparent, as if it had been exposed to X-rays. In the original photograph

the mouse is also shown somewhat transparent, indicating slightly the bones.

I also show you in Fig. 12 and upon the screen a slide which I have made of a radiograph of a human hand. This was exposed for eight days, and bears resemblance to an X-ray picture which has been overexposed. In making a faint print of this, a slight trace of the bones is shown and the embalming material employed is brought out strongly. This is, perhaps, the first picture made of the human hand by means of radium and it would not have been possible, of course, to have exposed a living person to these rays for even a small percentage of this length

FIG. 11.—Radiograph of Mouse Caught in Trap and Exposed to Tube of Radium for Three Days. (Note Transparency of Wood, as with X-rays).

of time. Perhaps subsequent experiments will bring out much more strongly the bone structure (the irregularity in the fingers is due to their being somewhat cramped).

As X-rays will excite phosphorescence in many substances, one would naturally wonder whether there were any X-ray characteristics in phosphorescent substances.

An interesting experiment is shown in Figs. 13 and 14. In the former experiment, I have placed strips of various metals, such as brass, iron, copper, tin, lead, tin foil, aluminum, platinum, magnesium, etc. and strips of carbon, vulcanite, glass, mica and celluloid.

FIG. 12.—Radiograph of a human hand made by Radium in 8 days' time.

FIG. 13.—Photograph Made by Phosphorescent Sulphide of Calcium of Iron, Brass, Copper, Tin, Lead, Aluminum, Platinum, Tinfoil, Magnesium, Carbon, Glass, Mica, Celluloid, Vulcanite, etc., and Strip of Black Paper. (See Fig. 14.)

Across the middle of the plate I have placed a strip of thick black paper cut from an X-ray plate envelope. I then sprinkled over the entire plate by means of a sieve sulphide of calcium, which I had made brilliantly phosphorescent by exposure to burning magnesium ribbon. The only substances which allowed the light to pass through at all were the glass, mica and celluloid, the other substances, including the paper, being very opaque, showing apparently only the presence of ordinary light rays. This plate was placed for twenty-four hours in a dark room.

FIG. 14.—Radiograph Made by Radium of Same Substances as in Fig. 9. Note Black Paper is Transparent, as are Certain of the Other Substances especially those directly below the Radium.

In Fig. 14 are shown some substances similarly arranged, but exposed to a tiny tube of radium of 7,000 radioactivity, which was placed 3 inches above the plate and near the center. The exposure was made for twenty-five hours; and it will be noted that the strip of black paper has entirely disappeared, and the various substances underneath it have been penetrated to a greater or less degree; particularly, those nearest to the radium.

A bibliography of "Radio-Activity," even at this early date,

would be very extensive; among the publications containing the most important contributions are *The Phil. Mag., Comptes Rendus, Ann. der Physik, Revue Gen. des Sciences, Nature, Jour. de Phys., Soc. Francaise Phys. Bulletin, Chem. News, Phys. Ges. Verk., Phys. Zeit, Science Abstracts, Wied. Ann., Proc. Royal Soc., etc.*

The Properties and Applications of Selenium.

The extraordinary property which selenium possesses of varying its electrical resistance on exposure to light is a phenomenon which has been known for a long time; but the commercial applications of this peculiar property possessed by selenium have not been properly appreciated up to the present time.

It is my purpose to invite your attention this evening to a number of applications of selenium which the writer believes will prove of no small interest to the electrical engineering profession, and perhaps stimulate investigations in this most promising field.

The Swedish scientist, Berzelius, discovered selenium in 1817, as a by-product from the distillation of sulphuric acid from iron pyrites. The proximity of the earth and moon suggested to Berzelius the name "Selenium" after the Greek "selene" (moon); this being the result also of the striking similarity of the properties of selenium with those of tellurium, which is a term derived from the Latin "Tellus," (earth.) Its atomic weight is 79.5; specific gravity when crystalized, 4.788; its observed vapor specific gravity at 2588° F. 5.68. It is a non-metallic element, which possesses characteristics similar to phosphorus, sulphur and tellurium. When melted at 212° Centigrade and allowed to cool rapidly, it forms a brown amorphous mass of conchoidal fracture. In this condition it is a high class insulator. It has been said that a small piece of it would represent the resistance of a wire stretched from the earth to the sun. When heated for quite a time at a temperature of 100° Centigrade, selenium becomes a conductor of electricity to a limited degree, this increasing with an increase of current and varying according to the direction. Selenium has neither taste nor smell.

The red vapor rising from selenium when subject to intense heat is exceedingly poisonous, and care should therefore be taken when experimenting with selenium in liquid form.

Selenium is usually supplied commercially in a vitreous form. Here are some samples of it, and you will note that it is as structureless as glass and resembles black sealing wax. I also

have here some amorphous selenium in which form it is a finely divided brick red powder. This changes into vitreous selenium when exposed to a temperature of from 80° to 100° Centigrade. In order to obtain crystalline selenium, in which form it is useful for selenium cells, it must be kept as already stated at from 100° to 200° Centigrade for some time, the black mass being changed into a hard slate-colored metallic looking substance. In this form even the thinnest films are opaque to light, whereas in the vitreous form the film would be transparent and ruby red in color. I have some of these films here for your examination.

Selenium is to-day employed to a considerable extent for the coloration of glass.

In 1851 Hittorf first discovered the effects of temperature on selenium; but it was not until February 12, 1873, that Mr. Willoughby Smith sent a communication to President Latimer Clark, of the Society of Telegraph Engineers of London, calling attention to the effect of light in reducing the resistance of selenium. An assistant of Mr. Willoughby Smith, a Mr. May, who was a telegraph clerk at Valencia, called attention to the fact that some pencils of selenium which had been used to give a high resistance in connection with some of the cable testing work conducted by Mr. Willoughby Smith, showed a marked change in resistance when the sliding cover of the box which held the selenium was removed, and the selenium was exposed to sunlight. These selenium pencils varied in length from 5 to 10 centimeters, and were 1 to 1½ mm. in diameter; they were hermetically sealed in glass tubes with connecting wires of platinum at each end. Little credence was given to the original announcement; and it was only after Earl Ross verified this statement, and proved that the action was due solely to light, and showed the effects of the light of different portions of the spectrum, that it met with serious consideration. Since that time much work has been done in investigating the properties of selenium, especially by Messrs. Shelford Bidwell, J. W. Giltay, Lord Ross and Sale, Draper and Moss, Hittorf, Adams and Day, Ayrton and Perry, Sir W. C. Siemens, Werner Siemens, Mercadier, Fritts, Minchin, Ruhmer, Webb, Bell and Tainter, and many others.

Alexander Graham Bell some twenty years ago made some interesting experiments with his radiophone, a diagram of which is shown in Fig. 15, in which a mica or glass diaphragm covered with a silvered foil was used to reflect a powerful beam of light upon a selenium cell placed in the focus of a silvered reflector.

To the selenium cell were connected a pair of telephones and a battery. At the back of the silvered diaphragm was a flexible tube and mouth piece into which words were spoken. The sound waves causing the diaphragm to vibrate sent pulsations of the reflected light upon the selenium cell, producing corresponding variations in its resistance and reproducing audible sounds in the telephone. Prof. Bell only used this over very short distances.

In 18 8 Prof. H. T. Simon of the University of Göttingen, discovered that an arc lamp, the circuit of which was in proximity to a telephone circuit, was caused to vibrate very perceptibly and he devised his interesting speaking arc by means of which he superimposed the sound waves produced by the telephone upon the circuit in which the arc was placed. He connected the lamp circuit with the secondary winding of an induction coil,

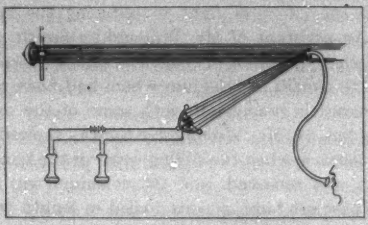

FIG. 15.—Prof. Bell's Radiophone.

the primary circuit being connected with the carbon transmitter, and a battery. The sounds thus produced originally were very weak; but by employing a suitable carbon microphone, the sound was reproduced to large audiences.

Conversely, the arc could also be used in conjunction with telephone receivers to receive sounds.

It is also found that the transmitter battery may be omitted, and a shunt taken from the arc circuit may be used with the transmitter and a suitable resistance. Again, this resistance may be displaced by storage batteries; and in this case to secure the most satisfactory results, self-induction ("reaction coils") should be placed in the circuit of the arc lamp, allowing the direct current to pass without obstruction; but offering extremely high resistance to the alternating currents produced by the carbon transmitter. By compensating in this way any disadvantage in the use of the shunt is done away with.

The transmitter may also be placed in shunt with the reaction coil instead of in shunt connection with the arc lamp, and this has the advantage that the rheostat used with the storage batteries may be omitted, provided the windings of the reaction coil are suitable for use as a resistance. By this arrangement, the lack of self-induction in the transmitter circuit permits of a very clear and distinct reproduction, sufficient to be heard by large audiences.

Mr. W. Duddell, of England, has made some most succesful talking arcs, which the writer had the privilege of seeing in London over two years ago. In his arrangement in the secondary circuit is placed a condenser, which prevents the lamp current entering the induction coil; but allows the induction current in the transmitter circuit to pass without obstruction; and this arrangement has the effect of greatly increasing the sound. By employing a condenser of from three to five microfarads, he compensates for the difference of phase produced by the self-induction in the circuit, thus producing the highest effect in the arc.

When Duddell uses the arc for transmitting sound waves, he employs in the shunt circuit to the arc a condenser and receiving telephone. It is advisable to employ as long an arc as possible. It has also been found that the Moore vacuum tube and the various types of mercury arc, such as Arons, Hewitt and Weintraub, are very suitable for this class of work, as well as the carbon arc; and where the latter is employed, either cored or treated carbons are advisable.

The theory advanced to account for the phenomena of the speaking arc, is that variations in temperature of the arc are produced by the variations of the current, and the change in the Joule effect produces a corresponding variation in the volume of the conductive gases in the arc.

The most successful and most extensive experiments which have been made with the speaking arc are those of Mr. Ernest Ruhmer, of Berlin, Germany, who has employed it in conjunction with his selenium cells for wireless telephony and with remarkable success. In Fig. 16 is shown the apparatus employed by Mr. Ruhmer, with which he has succeeded in transmitting speech over a beam of light 4½ miles in length*. Mr. Ruhmer's apparatus is shown in the illustrations thrown upon the screen,

* Mr. Ruhmer has recently written the author that he has succeeded in talking over a beam of light a distance of over ten miles.

and in Fig. 17. In his experiments he employed an arc lamp with a flaring arc 6 to 10 mm. long, using an e.m.f. of 220 volts, the current varied from 4 to 5 amperes at 1 to 2 k.m., 8 to 10 amperes for 3 to 4 k.m., and 12 to 16 amperes for 5 to 7 k.m., and the resistance of his selenium cell was 120,000 ohms in the dark, this falling to 600 ohms in full sunlight. For the transmitting end, Mr. Ruhmer employs a carbon transmitter and a battery superimposing waves on the arc light circuit; and the beam of light is reflected to some distant point, where it is received by a parabolic reflector; in the focus of which is placed a selenium cell connected with a battery and a pair of very sensitive telephone receivers.

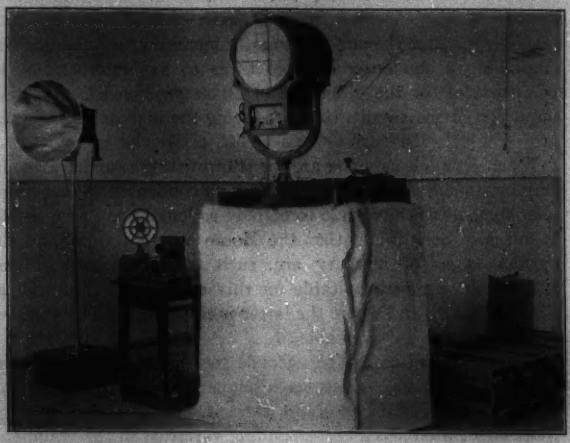

FIG. 16.—Ruhmer's Apparatus for Long Distance Telephony over a Beam of Light.

Mr. Ruhmer has conducted extensive experiments both by night and by day, and even during fog and rain on the Wannsee, near Berlin. On the screen you will see an illustration of his apparatus in actual work at night. (Fig. 17.)

Some time ago I suggested to Mr. Ruhmer the employment of Edison's tasimeter, the extraordinary sensitiveness of which is well known. He informed me that he had tried this; but had found it too "lazy"; and stated that he has secured most promising results by the employment of the thermopile; and with this he expects to be able to transmit sound over many miles.

Mr. Ruhmer is about to commence extensive experiments under the direction of the German Government in connection with the Imperial fleet in the Baltic Sea.

Mr. Ruhmer has also suggested the employment of his photographophone, which I shall describe later, as a means of recording messages received at a distance.

Doubtless many present remember the interesting experiments made by Mr. Hayes at the Electrical Exhibition held in Madison Square Garden in May, 1899, in which music was transmitted over a beam of light. At one end of the garden was placed a telephone, before which a cornet was played, causing waves of

FIG. 17.—Ruhmer's Wireless Telephone Receiving Station at Wannsee, Berlin (taken at night).

current in the telephone circuit to be superimposed upon those in a neighboring arc light circuit. The light rays from this arc lamp were reflected across the Garden, where they were received in a parabolic reflector in the focus of which was a glass bulb containing filiments of carbon. This bulb was connected to a pair of ordinary phonograph listening tubes. The varying light which fell upon the carbon caused variations of temperature inside of the glass bulb which produced the original sounds in the listener's ear. A bulb simply coated with lamp black and containing nothing but air, would answer the purpose just as well.

Selenium cells may vary in resistance from 2,000 ohms to 500,000 ohms or more in the dark; and certain cells may be five

to twenty times as good conductors of electricity in light as in the dark; and in the case of other cells, notably that of the Fritts' cell, which I have here this evening, and that of the Ruhmer cell used in his Wannsee experiments, will have two hundred times the conductivity in light that it has in the darkness; and the ratio may be even higher. They are usually made by winding carefully two separate lengths of wire, either of copper, brass, German silver or platinum, equidistant throughout their entire length upon such substances as slate, glass, mica or porcelain. The selenium is then spread thinly over the wires forming an insulation between the two windings. This form of cell was invented by Mr. Shelford Bidwell, F. R. S. No small amount of skill is necessary to wind these fine wires evenly and equidistant, and to cover successfully these wires with the selenium coating. One way of coating frequently employed is to warm the cell on a metal plate or sand bath heated by a Bunsen burner. When the stick of selenium laid on the plate shows evidence of melting, which takes place at about 120° Centigrade, it is drawn slowly over the wires, coating the same thinly and evenly. A steel spatula or a strip of mica can be used with advantage.

Or the strip of material on which the wires have been wound would be laid upon a brass plate covered by a strip of this mica, this being placed upon a tripod with a Bunsen burner underneath. Powdered vitreous selenium may thus be spread evenly over the wires, and the selenium will shortly melt; and where the portions of it crystallize, forming hard lumps, it will be necessary to continue the heating until these disappear. Then the selenium may be spread uniformly with a piece of steel, or better still, a strip of mica, care being taken to cover up the edges. Mr. Bidwell states that the temperature should be carefully regulated, as when it is too low hard crystalline lumps will form, and when too high the surface tension causes the selenium to form in drops, and it is then as difficult to spread as if it were mercury. The proper temperature should be only just above 217° Centigrade; and then the selenium is in a plastic semi-fluid condition and can be easily manipulated. When a satisfactory surface is secured, the cell should be placed upon a thick copper plate to cool quickly, when the selenium becomes black and lustrous. The Bunsen flame should then be turned down to give a temperature of about 120°, and the cell is then placed upon the hot plate; and shortly, the whole surface of these turns to a dull gray color. The temperature is then cautiously raised until signs of melting begin to

appear, generally near one of the edges. When this occurs, the burner is instantly withdrawn and the flame lowered. The dark spot recrystallizes in the course of a few seconds, and the burner is then replaced and left for four or five hours, during which time the Se should be only a few degrees below the melting point. The coil should then be gradually cooled by lowering the flame gradually for an hour. This process of long heating and slow cooling is generally spoken of as " annealing."'

In Fig. 18 is shown an illustration of a number of types of selenium cells, including the Bidwell, Ruhmer, Giltay, Webb

FIG. 18.—Types of Selenium Cells.

Clausen & Bronck, Mercadier and Fritts, which I have brought with me for your consideration.

The two cells to the extreme right and left are modifications of Mr. Shelford Bidwell's cells, the original form of which consisted of two fine copper wires wound side by side on oblong strips of mica with melted selenium spread over the surface, the one to the left being manufactured by Ernest Ruhmer, of Berlin, and by Messrs. Clausen and Bronck, which consists of copper wire wound on slate. The one to the right is manufactured by Mr. J. W. Giltay of Delft, Holland, and consists of platinum wire wound on slate and covered with selenium. The four tiny cells shown against the white background are made by Mr. Hartwell W.

Webb, of New York City, and consist of German silver wire wound on slate. The cell to the right is placed in a sealed flat glass tube. The two lower Webb cells are incased in ebonite. The small round cell is a tiny Mercadier cell made by Mr. Webb. The method of making the Mercadier cell is to use two narrow ribbons of sheet brass or foil, separated by a ribbon of parchment paper rolled up like a spiral spring. This is held between wooden clamps, one surface being ground and polished off smoothly, and a thin layer of selenium being spread over it. An excellent idea of this cell may be had by noting Fig. 19, which shows the standard form.

In the center of the picture is shown a cell of Mr. C. E. Fritts, of New York City, for which I am indebted to my friend Prof. Geo. F. Barker. In the Fritts cell a very thin layer of selenium from one one-thousandth to one five-thousandth of an inch

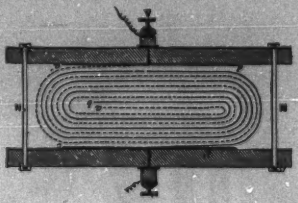

FIG. 19.—Mercadier's cell (block and dotted lines represent the two ribbons of brass).

in thickness is spread upon a plate of metal, generally zinc or brass. The selenium and metal plate form a chemical combination sufficient at least to cause the selenium to adhere and make good electrical connection. The upper surface of the selenium is then covered by a transparent conductor of electricity, preferably a thin film of gold leaf. Platinum or silver may also be employed. Thus the two surfaces of the selenium are covered by a metal and are connected to the two ends of the circuit. The upper or gold leaf surface, however, permits the light to pass through and affect the resistance of the selenium beneath.

The tall cell in the lamp socket shown is the latest form of Mr. Ruhmer's cell, and this type represents, I believe, the most important development which has been made in the selenium cell, and it has now become most stable and responds most rapidly to variations in illumination He employs two copper wires,

wound spirally side by side around a cylinder of porcelain, which, after the wires have been covered with selenium, is placed inside of a globe, from which the air is exhausted and it is mounted with a butt similar to an Edison incandescent lamp, and resembles a candelabra lamp. This makes a most convenient method of handling the cell; and by keeping it from the air the disadvantages inherent in all cells heretofore have been very largely done away with.

Another form of Ruhmer cell consists of two fine platinum wires wound on a glass cylinder 1¼ inches long and ¾ of an inch in diameter; the wires which are 1/32 of an inch apart are coated with selenium.

Selenium cells are very susceptible to moisture, and it is largely this taking up of moisture which produces the electrolytic effect in the cell, enabling one to connect it with a galvanometer and produce a current by merely focusing the light upon the cell. This phenomenon gave rise to the designation of the photo-electric cell.

Those who have worked with selenium cells know that heretofore they have been most unreliable; varying their resistances from time to time enormously; and in the case where copper wires are employed, there is a selenide of copper formed, which often renders the cells inoperative in a comparatively short time.

To some extent, the cells made originally have been protected by covering them with mica or lacquer or varnish; but placing them in an exhausted receptacle and mounting them in the manner devised by Mr. Ruhmer is, it seems to the writer, a most important step in the commercial development of the selenium cell.

Prof. Bell has made a number of types of selenium cells, his standard form consisting of alternate disks of brass and mica, with the mica disks slightly smaller than the brass, forming a recess for holding the selenium, which is spread over the surface. All the evenly matched disks are connected to one end of the circuit; and all the old disks to the other end. The cylindrical form of the cell enables it to be acted upon from all directions, when placed lengthwise in the focus of a parabolic reflector. This is also of great advantage in the Ruhmer type of cell.

Selenium cells possess the remarkable property of recovering the original resistances upon the removal of the source of light.

It is well known that in the case of the radiophone, if a beam of sunlight be thus intercepted by a blackened perforated revolving

disk, a musical note, varying in pitch with the speed of the disk, will be produced in a rubber tube held at the opposite side of the disk. I have here one of the original forms of radiophones.

A piece of apparatus has been devised consisting of a disk with slits near the edge which is placed near an incandescent lamp, and a selenium cell. If the selenium cell is connected to a telephone and battery, and the disk is rapidly revolved, a musical note will be produced in the telephone, the pitch of which will correspond to the speed of the revolving disk.

Mr. Giltay has recently written me suggesting a very pretty experiment in this line, in which a double vaned Crookes' radiometer is placed between a selenium cell and an arc light shielded by an alum cell. The light from the arc lamp causes the radiometer to revolve intermittently screening the selenium cell and producing a musical note in the telephone attached thereto, the pitch of which is in accordance with the speed of revolution of the radiometer.

I have here to-night two forms of flame telephone transmitters, one of which was presented to me by Mr. Ruhmer, and the other I have purchased from Mr. Giltay, which I have mounted as you see it here and as illustrated in Fig. 20 (about 24 volts are required, depending upon the selenium cell). In each case you will note that I have an acetylene generator which conveys gas to the interior of an otherwise empty telephone transmitter. The diaphragm of these transmitters is made of pig-skin, or a similar material. A tiny pipe runs from the back of the transmitter, and ends in one case to a single acetylene jet, and in the other case to three acetylene jets. By talking against the pig-skin diaphragm, the gas inside is made to vibrate and produces a manometric flame. This flame throws its light upon a selenium cell, to which is connected a battery and a pair of very sensitive telephones between 100 and 200 ohms for each cell of battery, in which the sounds spoken into the transmitter are most perfectly reproduced. A thin sheet of paper inserted between the flame and the selenium cell serves to cut off all sound. It is self-evident that these telephone receivers might be at any distant point. I have worked them over considerable distances.

In Fig. 21 are shown a number of most interesting applications of the selenium cell in conjunction with a battery and relay, used for starting a motor, ringing a bell, firing a cannon; blowing a horn, and lighting incandescent lamps, all of which experiments

I shall hope to show you in actual operation, as I have had them working most successfully in my laboratory; and you will see that by merely passing my hand before the selenium cell, I can start and stop the motor, turn the light on and off, and ring the bell and blow the horn, or I can fire this cannon, start my phonograph talking, etc. I am indebted to the courtesy of the Marconi Co. for the large relay used in certain of these experiments.

I have here also a 3 h.p. motor, driving a 1½ k.w. generator and

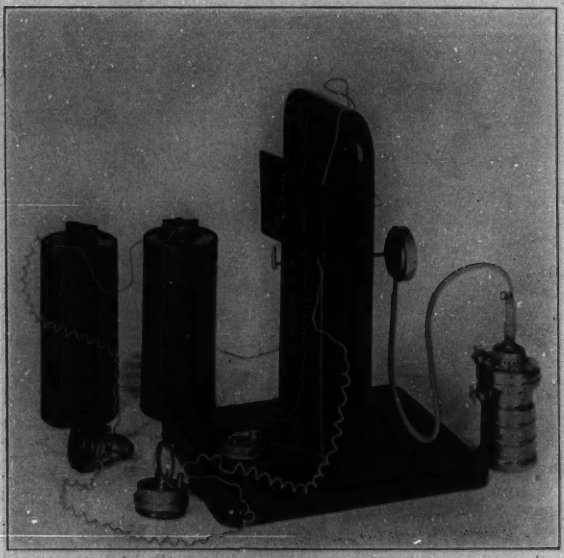

FIG. 20.—Manometric Acetylene Flame Transmitter with Selenium Cell, etc. —(a battery of about 24 volts employed.)

supplying these lamps which have been courteously supplied by the General Electric Co.; and by means of this selenium cell, relay, battery and a motor starter, for which I am indebted to the Cutler-Hammer Co., I hope to be enabled to start and stop the motor by merely passing my hand before the selenium cell.

In Figure 22 is shown a portion of the stage setting at the

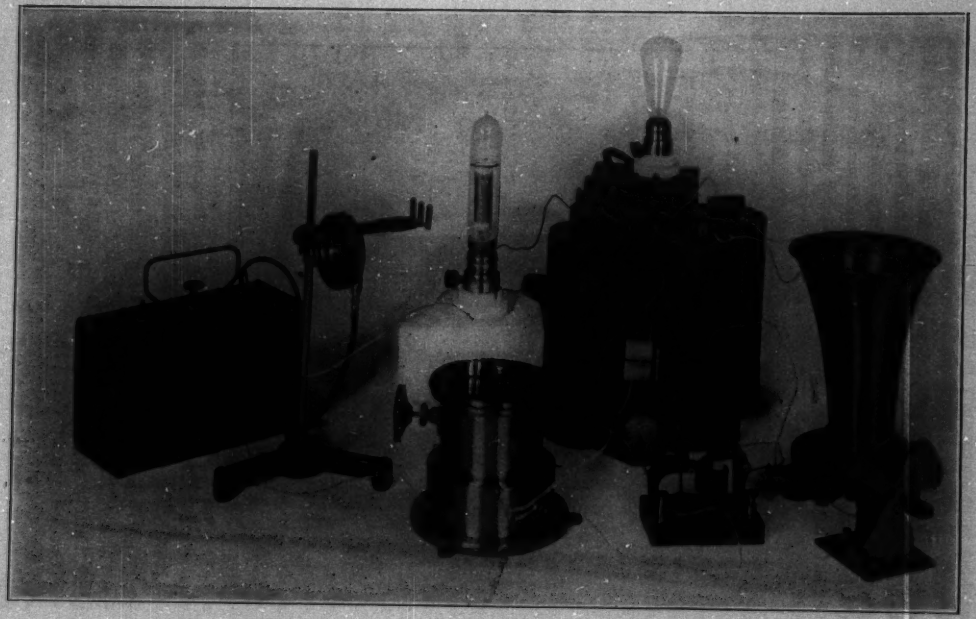

FIG. 21.—Acetylene Flame Apparatus, Ruhmer Selenium Cell, Relays and Battery for Operating, Electric Lamp, Bell, Motor and Horn. (A 3 H.P. Motor and Generator were also similarly operated and a cannon fired.)

lecture, and shows in the foreground the three horse-power motor and generator which supplied a bank of lamps, and which plant was started and stopped many times when the author passed his hand between the acetylene flame and a selenium cell. The frontispiece is a general view of the stage setting in the College of the City of New York, and was taken shortly before Mr. Hammer's lecture.

In 1886 the writer attended a convention of the Edison Association of Illuminating Companies at Rochester, New York, and

FIG. 22.—Three H. P. Motor and Generator supplying Bank of Lamps and operated by shielding with the hand a Selenium cell from an Acetylene Flame.

during a discussion of contract systems versus meter systems, he gave his experience as chief inspector of central stations of the Edison Company, in dealing with the difficulties met with in supplying light by contract; and he then described a practicable method of utilizing selenium cells to control relays and magnets which would throw off the electric lights on the approach of day and on again at night, thus solving the difficulty of street lighting, and other circuits intended to operate only at night.

On February 12, 1890, in a paper on some experiments with

selenium cells, Mr. Shelford Bidwell showed a relay operated by a selenium cell, which threw on an electric lamp and rang a bell; and he suggested the protection of safes and strong rooms by selenium cells, which would be affected by the light from a burglar's lantern, thus giving an alarm. He also spoke of their being used to give notice of the extinction of railway signal lamps and ship lights, and stated the following: "But I do not at present attach any serious importance to such practical applications of these devices. I regard them simply as offering somewhat attractive illustrations of the effect of light upon the resistance of selenium."

This is an important statement from the greatest authority on the subject of selenium, but to-day it will not hold good.

I hold in my hand a small vial containing some "thermit," which was discovered by Dr. Goldschmidt. It consists of oxide of iron, such as one would get off of a blacksmith's anvil, or from the rolls of a rolling mill, and is mixed with powdered metallic aluminum. A red hot iron or molten cast iron poured into this mixture produces no effect; but if a little barium preparation or magnesium powder be placed on top of this mixture and touched off by a match, an extraordinary reaction takes place, producing a temperature of about 3000° C., and the mechanical equivalent of a kilo (2.2 lbs.) of thermit is about 1,730 horsepower seconds or 1,273 kilowatt seconds.

I have seen some very interesting experiments made in welding girder rails, pipes, etc., by this process, and have here some interesting samples of manganese, chromium, ferro-titanium and other metals prepared in this way.

I have also seen steel safes in which enormous holes had been burned by employing thermit; and it would be possible for a burglar to carry some thermit in his pocket and burn a hole in a safe large enough to insert his arm and extract the valuables.

I also saw in Germany last summer a substance called "anti-thermit," which it is intended to place in the lining of safes to prevent the reaction taking place, thus protecting the safe. But a simple plan would be to place a selenium cell in or near the safe, so that the moment the reaction was started, a signal would be given to the police in a similar manner, as suggested by Mr. Bidwell in the case of the burglar's bull's-eye lantern.

An important commercial application of the selenium cell has recently been made by Mr. Ernest Ruhmer in connection with his electrically controlled buoy illustrated in Fig. 23.

Pintsch has constructed a large number of buoys containing compressed gas, which would last from one month to upwards of a year; but it was heretofore necessary to burn these lights day and night, it being often impracticable by reason of distance at which they were placed, and frequency of storms, etc., to switch off the gas so that it would not burn during the day time.

Mr. Ruhmer has placed one of his selenium cells in the top of such a buoy connected with a switching device which, as soon as the sun rises in the morning, causes the selenium cell to reduce its resistance, this causing the switching device to turn off the gas, which is again turned on upon the

FIG. 23.—Pintsch Gas Buoy Controlled by a Ruhmer Selenium Cell, Battery and Switch Mechanism.

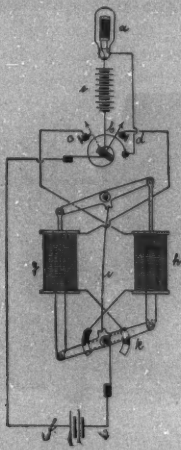

FIG. 24.—Diagram of Circuits of "Selenium" Buoy.

increase of resistance of the selenium cell by the approach of night-fall, or if desired in the case of a storm coming up. A buoy containing sufficient gas for one month could thus be made to answer without recharge for from three to five months.

The arrangements of the circuits as originally devised by Mr. Ruhmer is shown in Fig. 24. The voltmeter needle has been replaced by a relay, and the apparatus simplified. A single dry cell is interpolated in the selenium cell circuit, as usually employed on the buoy; and this cell will last a year or more, and with the relay, it is placed in the bottom of the buoy and arranged to be absolutely waterproof.

When I was in Berlin last August, one of these buoys had been in operation since the previous October, turning the light on and off every night and morning; and Mr. Ruhmer has recently written me that it is still operating successfully, as are others which he has placed near Hamburg and in the Baltic Sea.

Mr. Ruhmer has also constructed an apparatus employing the selenium cell to which he has given the name "photographophone," which is one of the most remarkable pieces of scientific apparatus that it has ever been my pleasure to see. Figs. 25, 26

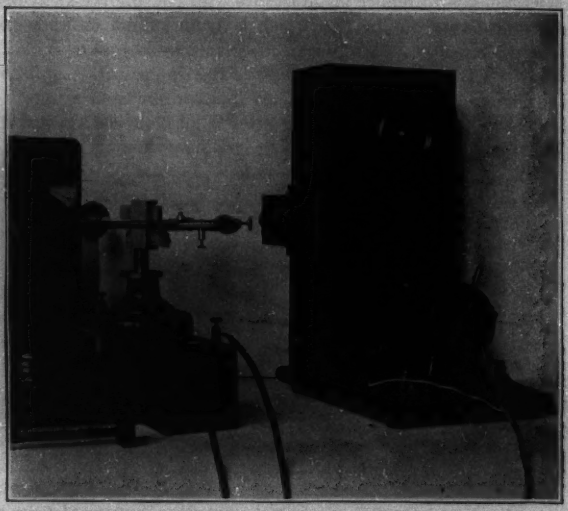

FIG. 25.—Ernest Ruhmer's Photographophone, Showing Exterior View, together with Telephone Transmitter and Arc Lamp.

and 27 illustrate the general construction of the apparatus, which I shall further illustrate by accompanying lantern slides. In Fig. 28 the apparatus is shown diagramatically and in Fig. 27 the inventor is shown listening to the photographophone reproducing speech and music. It consists of a box containing a gelatine or celluloid film, such as employed in moving picture machines, which is driven at high speed by means of an electric motor. In the front face of the box is set a cylindrical lens about the size of one's little finger. A short

distance away from the box is placed an arc lamp and a telephone. Words spoken or sung into the telephone superimpose the waves in the telephone circuit upon the current flowing in the arc light circuit, and cause a corresponding variation in the light of the arc. The rays from the arc lamp pass through the cylindrical lens already referred to, and are caused to fall in sharp white lines on the moving sensitive film. This film, upon being taken out of the box and developed, shows a series of perpendicular striations parallel to one another, which are really a photographic record of the sound waves originally entering the telephone transmitter. Where the striations are fine and close together, the pitch is high, but where they are broader and farther apart the pitch is low. Strips of the films or photograms are shown in Fig. 29. The developed film is next placed back into the box and the motor again started. The arc lamp remains in its original position, but

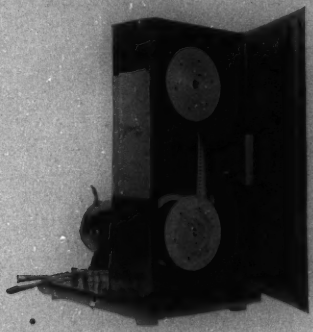

FIG. 26.—Showing Interior of Ruhmer's Photographophone.

burns steadily as the telephone is not operated. The rays from the arc lamp passing through the lens are therefore quite uniform, and the moving gelatine strip acts as a screen to cut off these rays, allowing the light intermittently to fall upon the selenium cell at the back of the box, producing a variation in its resistance and a corresponding effect in the telephone receivers connected thereto. A battery is also interpolated in the circuit with the selenium cells and the telephones. By holding these telephones to the ear, the reproduction of the sound is perfect, as I can vouch for from personal experience with the apparatus.

Mr. Ruhmer contemplates utilizing this photographophone as a receiving instrument with its wireless telephone system, in which he employs a beam of light, as already described.

Mr. Shelford Bidwell has also made a device for producing pictures or writing at a distance by combining the properties of selenium with the chemical telegraph.

Various inventors have endeavored to solve the problem of seeing what goes on at a distance by employing selenuim. Among these are Perosino, Senlecq, de Paioa, Cary, Sawyer, Larroque, Nipkow, Gemmill, Liesegang, Heinzerling, Edison, Stern, Jan Szczepanik, Dussaud, Otto von Bronk, von St. Schneider, Ayrton and Perry, Korn, and others, who have proposed various methods employing images thrown on ground glass or through a photograph negative, or upon mirrors swinging synchronously, by or

FIG. 27.—Mr Ernest Ruhmer Listening to his Photographophone.

using revolving perforated screens, for cutting off the beams of light, multiple selenium cells which would be affected by high lights and low lights of the original picture, etc., these devices affecting some method of illumination at the receiving end or producing an electrochemical action such as is produced by the usual chemical telegraph systems, or controlling an electropantograph system such as Gray's telautograph. These various inventions have been termed the telescope, telephote, telectroscope and the telephotograph. But these devices have thus far reached little further than descriptive matter, drawings and crude experiments.

Various people have suggested the use of selenium cells for photometric purposes; and it is interesting to note that Mr.

Latimer Clark suggested this application the evening in which Mr. Willoughby-Smith first brought to public notice the phenomena of variation in resistance of selenium when exposed to light, to which I have already referred.

Mr. Fritts has suggested making a form of photomoter which would be sensitive to lights of different color, as well as of varying candle power, by employing as a film on the surface of his cell a gold foil which transmits green rays, a silver foil the blue rays, and so on; and suggests that a solid transparent conducting film which would transmit all of the rays would be far better and thus remove the color stumbling block in photometric work.

Sir William Crookes has constructed an exceedingly interesting type of radiometer, in which he has coated the revolving vanes on one side with selenium, and on the other with chromic acid. He

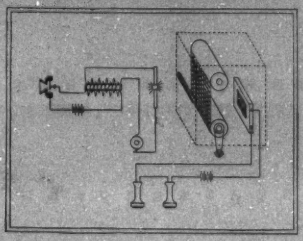

FIG. 28.—Showing General Arrangement of Circuits of Ruhmer's Photographophone.

found that the white light from a sperm candle repelled the selenium, while the yellower light of the wax candle repelled the chrome, thus indicating the relative absorptive powers of the different substances for rays of different refrangibility, resulting in mechanical motion; just as the same selective capacity operates in photography as chemical action.

In 1891 Prof. Barnard of Lick Observatory employed a selenium cell as a device for automatically detecting comets, and Minchin has employed the selenium cell quite extensively in his astronomical investigations.

In Fig. 30 is shown a curve which Mr. Ruhmer recently sent me which shows some observations made by means of his selenium cell during an eclipse, these being the only observations which anyone was enabled to make at that time, on account of stormy weather. Mr. Ruhmer has prepared an interesting paper bearing on this and other applications of the selenium cell to meteorology. He made his observations on October 31, 1902.

Selenium is found in Vesuvian lava, and in natural sulphur as a sulphur selenide in the Lispari Islands. It is also found in Norway and other iron pyrites. It occurs in meteoric iron and in such rare metals as eucarite as a selenide of silver and copper in Sweden and Chili; crooksite, a selenide of copper and thallium with a little silver, from Norway; as clausthalite, a selenide of lead in the Hartz Mountains, from Zinken and Clausthal, in Inverg, Rheinberg, Saxony, Rio Tinto, Spain, Mendoza, South America; as riolite at Culebras, Mexico; as Lehrbachite, a

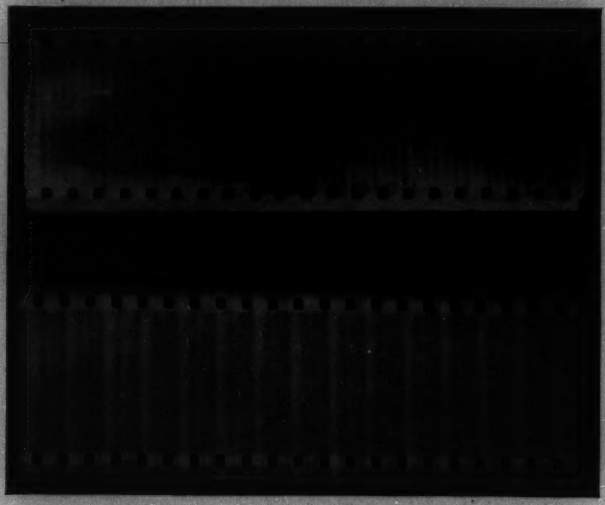

FIG. 29.—Photogram as used in Ruhmer's Photographophone (High Pitch Tones above, Low Pitch below).

selenide of mercury and lead from the Hartz Mountains; as zorgite, a selenide of copper and lead from Glasbach in the Hartz Mountains. Selenium, although widely distributed over the globe, occurs only in small quantities and in some instances is found in native state.

Selenium is placed among the rare metals. Chemically pure crystalline selenium costs about $1.00 per gramme; and the ordinary commercial article about 10 cents per gramme

The Bibliography of selenium is quite extensive. Those interested in the subject will find an excellent paper by Mr. A. P. Saunders

in the *Jour of Chem.* for June, 1900. The paper contains many references, and is entitled "Allotropic Forms of Selenium."

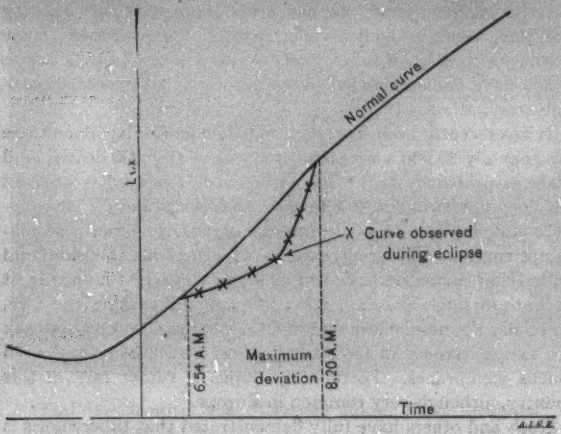

FIG. 30.—Curve Taken with Ruhmer Cell During Eclipse, Oct. 31, 1902

THE TREATMENT OF DISEASE BY ULTRA-VIOLET RAYS

PROF. NIELS R. FINSEN.

Some professional matters detained the writer in Copenhagen last summer for several weeks, and during his stay in that city he had the privilege of visiting the Finsen Light Institute at Rosenvaengat, a suburb of Copenhagen, and was enabled to investigate the system for the treatment of disease by light, inaugurated by Dr. Niels R. Finsen. In Figs. 31 and 32, are shown views of the operating room at the Finsen Institute, where a large number of patients from various parts of Europe were undergoing treatment at the time of my visit.

Dr. Finsen has conducted very extensive and most painstaking

researches into the bacteriacidal effects of light, and he has found the violet end of the spectrum to possess remarkable curative powers, and he has also found that by utilizing the blue, violet and ultra-violet rays of the spectrum, those loathsome diseases of tuberculosis of the skin and lupus, diseases which have baffled surgical skill heretofore, have been successfully combatted.

It has recently been stated that in New York City alone there are annually 20,000 cases of tuberculosis, with 8,000 deaths; and there is probably no disease with which mankind is afflicted which compares in deadly character to tuberculosis.

In affecting certain of the internal organs, it is known as consumption, and appearing externally, attacking the skin and underlying tissues, it is known as lupus vulgaris. As a rule, it appears in single patches, most frequently attacking the face, especially the nose, cheek and mouth. It may, however, attack the extremities or, in fact, any portion of the body and even mucus membranes. Fortunately, lupus is rather rare in this country, although very common in Europe.

Koch and others have fully demonstrated that tuberculosis is due to the presence of specific organisms named "tubercle bacillus," which have been found to be present in both the internal and cutaneous forms of the disease.

Doubtless many present remember the "blue glass craze," which swept over the country in 1876, or thereabouts.

I have with me here a copy of General A. J. Pleasonton's book entitled, "Blue and Sunlights, Their Influence upon Life and Disease," which I picked up in a second-hand book store some years ago; and I would commend the examination of this book to all who are interested in the subject. General Pleasonton and his system were condemned to both abuse and ridicule. Dr. Finsen, however, says, "The General was absolutely on the right track."

For a considerable time Finsen's work received little credence and no encouragement; but he persisted in his investigations, and the results secured by him finally bore fruit, and to-day the world rings with his praises. In all parts of the civilized world his work is being taken up, and institutes are being founded for the treatment of disease by light rays—particularly the ultra-violet light. In England the initiative was taken by Queen Alexandra, and in Russia by her sister, the Czarina, they both investigating the system while visiting their father, the King of

FIG. 31.—Showing Main Operating Room, Finsen Institute, Copenhagen.

FIG. 32.—Showing Arc Lamp and Four Finsen Tubes in Use at One Time.

Denmark. Much has also already been done in the United States.

It will be remembered that during Queen Elizabeth's reign a certain court physician recommended strongly that patients suffering from small-pox should be kept in a room, the decorations of which, including the hangings, bed draperies, etc., should be red in color, claiming that the red light had a soothing effect upon the irritated portions of the skin, lessening the severity of the disease. Little importance was attached to this method, and the originator of it was branded as a Charlatan.

Prof. Finsen, has, however, found that this method of treatment of small-pox is of paramount importance. He has placed patients in a room into which the sun's rays could only penetrate through sheets of red glass, just as they would penetrate a photographic dark room; and he has found that patients placed in such a room prior to the most painful and most dangerous suppuration stage setting in, that suppuration has been entirely prevented and that the scarring has been in nearly all cases absolutely prevented, and in the few cases where there was any scarring, it was hardly perceptible. The disease has been in a much milder form, the fever usually accompanying the eruption disappearing, and the temperature remaining normal.*

He has found that the use of ultra-violet light on these patients very much aggravated the disease, and even in cases where patients were almost cured and they have been allowed to go out into the sunlight, the disease has at once been aggravated.

In connection with his investigations into the effects of light Finsen made some interesting and ingenious experiments upon earth-worms placed in a box, one-half of which was covered with red glass and the other half blue glass; and he found the blue light irritated the worms so they invariably crawled under the red glass, and a chameleon, placed with its body midway between the glasses, turned almost jet black under the influence of the blue rays, while that portion under the red glass remained nearly white, which Prof. Finsen says showed that the chameleon was altering its pigment cells to lessen the irritating effects of the blue light.

The ultra-violet end of the spectrum contains the most refrangible rays, and it is these rays which are so harmful in cases of smallpox; and it is also these actinic rays which produce sun-

* Prof. Finsen has recently written the author that placing the patients in a dark room is fully as efficacious as placing them in a room lighted with red rays only, the important thing being to keep the patient from exposure to the actinic rays.

burning, which one often experiences in the Alps, or any high altitude where the temperature may be considerably below zero; and there are doubtless many present who have experienced considerable effect similar to sunburning by working in close proximity to arc lamps.

While these ultra-violet rays are so harmful in the case of smallpox, they are of the precise nature which is most desirable in the treatment of such diseases as tuberculosis of the skin or lupus vulgaris. These rays not only destroy the bacilli, but they excite and stimulate nutrition and excite activity in granulation, thus assisting very greatly in the rapid recovery from the disease.

Doubtless the rays emanating from the sun are very rich in blue, violet and ultra-violet light; but the atmosphere readily absorbs these rays, and while Prof. Finsen for a time used the sun's rays in the treatment of tuberculosis of the skin and lupus he found that by employing the arc light the same effect could be produced in a very much shorter space of time; and that he was in this way, also, independent of weather conditions.

The arc light is much richer in ultra-violet rays than the sunlight; and Broca and Chatin of Paris have found that by placing an iron core inside of the positive carbon electrode, this arc was still richer in ultra-violet light, and Görl of Erlangen, has constructed a form of aluminum arc, in which four arcs were formed between five aluminum electrodes. I have here a modification of Görl's lamps constructed by Messrs. Waite & Bartlett of this city, in which there are four iron electrodes forming three iron arcs in series, which produce an intense source of ultra-violet light. which I shall presently show in operation.

Bang and others have also made arc lamps employing terminals of iron.

It is claimed that by employing the iron arc the same results which take an hour and ten minutes by means of the carbon arc can be accomplished in twenty minutes to half an hour; and also that so intense are these ultra-violet rays it is not necessary to use pressure to drive the blood away from the diseased part, and it is also unnecessary to use water to cool the rays.*

Drs. Piffard and Jamieson have suggested the use of suprarenal extract in the form of adrenalin chloride, which the former prefers to introduce into the skin around the diseased spot

* Prof. Finsen has recently written the author emphatically asserting that iron electrodes are not as efficacious as carbon electrodes as the rays from the iron arc, he claims, do not penetrate as deeply as the rays from the carbon arc.

by cataphorisis, thus producing a whitened area from which the blood has been withdrawn, which enables the treatment of this portion by the ultra-violet light, without pressure being applied, and the blood does not return for half an hour or more. The cataphoric electrode is covered with a thickness of lentine saturated with adrenalin connected with a positive pole of the battery, using a current of from three to four milli-amperes, the bleaching taking from four to five minutes' time.

The Roentgen rays have been found very effective in the treatment of certain diseases, especially where hard tubes are employed, and as we are considering particularly the treatment of lupus vulgaris, I would call attention to Fig. 33, which repre-

FIG. 33.—Lupus Vulgaris Cured by X-rays.

sents a patient treated by my friend, Dr. William H. King of this city, in which the X-Rays successfully cured a case of lupus vulgaris brought on by the patient's pricking a tiny boil on the side of his nose with a pin taken from the lapel of the coat of a friend who was suffering from tuberculosis (consumption). The rapid progress of the disease is shown in the illustration and was taken three weeks after using the pin, and was largely augmented by the man's age (45), and his being in poor health (a chronic rheumatic). Two bacterialogical examinations showed conclusive evidence of the presence of tubercle bacilli.

In Fig. 34 is shown the original blue lens used by Finsen when employing sunlight. It consists of a flask full of light blue ammoniacal sulphate of copper. The bottle with its contents

makes a plano-convex lens. The sunlight passing through this is found to work very well; but it was too slow, and the sun was frequently obscured. Finsen later used plain water, finding that the blue water cut off most of the ultra-violet rays and he found the clear water very largely absorbed the ultra-red rays which caused the heat.

In Fig. 35 is shown a form of telescope which is now adapted in standard practice at the Finsen Institute. It contains four rock crystal lenses, which act to cut off considerable of the heat rays but allows the ultra-violet light to pass through it.

FIG. 34.—Finsen's Original Blue Lens for Use with Sunlight.

It will be remembered that ordinary glass cuts off almost all of the ultra-violet rays, whereas a block of rock crystal 4.4 mm. thick will allow 60 per cent. of the ultra-violet to pass through it.

A part of the heat is also absorbed by the distilled water which is contained inside of the telescope. In order to keep this water cool, there is an outside jacket on the telescope, through which circulating water may be passed for this purpose. In Fig. 36 is shown the method of arrangement of the telescope and the arc lamp; and in Fig. 32 is shown a set of four of these telescopes arranged around the arc lamp and in actual operation. The arc lamp uses from 40 to 80 amperes and operates at 45 to 50 volts.

Blood is opaque to ultra-violet light, and it is therefore necessary to drive the blood away from the diseased portion which is to be treated. This is accomplished by what is known as a pressure glass shown in Fig. 37. It consists of a plano-convex lens of rock crystal kept cool by circulating water—the glass acting to focus the light on the diseased portion, and also to exert considerable pressure there.

The patient does not suffer from exposure to the rays; but after the treatment, which is usually an hour and ten minutes per day, he appears to be considerably sunburned. He is then allowed to recuperate until the next day, and the treatment is then repeated. After a series of these treatments, the patient is sent away apparently cured. Sometimes he does not return; but more often he must come back for a second or third, and even more series of treatments, due to the fact that certain of the

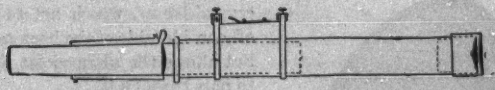

FIG. 35.—Finsen Telescope Tube, for Use with Carbon Arc Light.

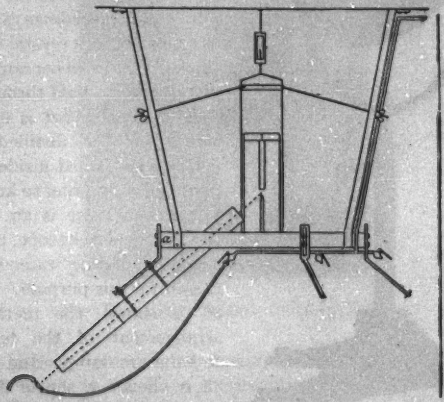

FIG. 36.—Showing Arrangement of Arc Lamp and Finsen Tubes.

microbes which have been deep-seated have worked their way to the surface, the disease having started anew.

It is said that out of over 600 cases treated at Copenhagen, there have been only 1 to 2% of failures due to fault in the treatment; but there have been cases where the disease has been in such an advanced stage and for such a very long period that it has not yielded successfully. But I was informed that in the majority of cases after very few treatments, the patients are dismissed absolutely cured. In order that you may properly

FIG. 38.—Showing Lupus Vulgaris Patients Before and After Treatment with Ultra Violet Light at the Finsen Institute, Copenhagen.

appreciate the remarkable results which have been secured by Prof. Finsen; and the stupendous importance which his successful combatting of these loathsome forms of disease represents to many of the most sorely afflicted people of this world, I have inserted in my paper several photographs, see Fig. 38, which I secured at the Finsen Institute; of patients afflicted with lupus vulgaris—these pictures showing them before and after the treatment with the ultra-violet rays produced by the arc light I feel that their presentation in this paper requires no apology, on the contrary, electrical engineers should feel a sense of pride that in the use of the arc light in this remarkable advance in medicine and surgery, their profession has contributed in no small degree.

Those caring to look up these and similar cases, will find full descriptions in English in " Phototherapy after Finsen's Methods," by Valdemar Bie, M.D., Prof. Finsen's Assistant (published

FIG. 37.—Pressure Lens.

by Lippincott), or Die Bekampfung des Lupus Vulgaris von Niels R. Finsen (Gustav Fischer Jena), and Die Finsen Therapie und ihr gegenwartigen stand in des Dermatolo-gie, von Dr. Forchhammer 1. Cohen's Buchdruckereien Kopenhagen).

The little cut of Prof. Finsen which heads this article is from an autograph portrait which Prof. Finsen presented to the writer, and it is sad to contemplate that this man who has conferred such a priceless boon upon humanity is himself an invalid, suffering from an incurable disease, and one which has made it at times well nigh impossible for him to prosecute his work.

The Finsen Institute was established in 1896, through the munificence of Copenhagen's public-spirited citizens, and through a gift by the city of the property on which it was erected.

The lecturer desires to express his appreciation of the services rendered by his assistants, Messrs. Varley, Lawton, Brown, Webb, Scheerer and Dow, and also to acknowledge the courtesies extended by the New York Edison Co.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, April 24, 1903.

The 176th meeting was held this date at 12 West 31st Street. President Charles F. Scott called the meeting to order at 8.20 P. M., and said that the Secretary had an announcement to make.

SECRETARY POPE:—At the meeting of the Board of Directors this afternoon, the following 211 Associates were elected:

Name.	Address.	Endorsers.
AALL, NICOLAI,	Assistant Switchboard Engineer, General Incandescent Arc Light Co., 572 First Ave., New York City; residence, 269 Kingsland Ave., Brooklyn, N. Y.	J. H. Hallberg. H. P. Ball. Louis Wintner.
ABLETT, CHARLES ANTONY,	Student, Testing Department, General Electric, Co. Schenectady, N. Y.	E. B. Raymond. W. I. Slichter. F. W. Carter.
ADAMS, SETH C.,	Salesman and Engineer, Westinghouse Electric and Mfg. Co., 120 Broadway, New York City; residence, New Rochelle, N. Y.	W. C. Hubbard. C. F. Scott. S. L. Nicholson.
ALKINS, ALBERT EDWIN,	Foreman in charge of Special Lamp Testing, General Electric Co.; residence, 192 S. Common St., Lynn, Mass.	R. Fleming. F. P. Cox. Elihu Thomson.
ALLEN, RODNEY D.,	Electrical Engineer, Smith and Allen, 1102 North American Building, Philadelphia, Pa.	H. F. Sanville. J. F. Stevens. Max Osterberg.
BACOT, EUGENE CYRUS,	Electrical Engineer, Highland Canal and Power Co., 315 Providence Building, Duluth, Minn.	N. T. Wilcox. E. H. Anderson. M. H. Gerry, Jr.
BAHNSON, FREDERIC FRIES,	Acting Sales Engineer Stanley Electric Mfg. Co., 29 Broadway, New York City.	C. Van Deventer. H. L. Morris. V. W. Bergenthal.
BALLOU, ALVIN M.,	Chief Electrician, Denver City Tramway Co.; residence, 135 West Maple St., Denver, Colo.	C. O. Poole. J. W. Stearns. R. W. Pope.

BARCLAY, JOHN C., Electrical Engineer, Western Union Telegraph Co., 195 Broadway; residence, Hotel Empire, New York City.
W. D. Weaver.
F. W. Jones.
W. R. Brixey.

BARKER, JAMES EDMUND, Electrical Engineer, Pacific Electric Railway Co., Los Angeles; residence, 409 N. Los Robles Ave., Pasadena, Cal.
D. E. Clough.
W. L. Puffer.
L. E. Reynolds.

BARNAY, JOHN MARTIN, Designer, Bullock Electric Mfg. Co., Norwood, Ohio.
W. D. Pomeroy.
P. B. Woodworth
G. N. Eastman.

BARRY, JOHN G., General Electric Co., Schenectady, N. Y.
J. D. Lovejoy.
H. D. Hawks.
T. P. Bailey.

BEACH, RALPH HAMILTON, Genefal Electric Co., 44 Broad St., New York City.
J. J. Mahony
W. B. Potter.
G. F. Sever.

BECKSTRAND, ELIAS HYRUM, Instructor, Engineering Department, University of Utah, Salt Lake City, Utah.
J. F. Merrill.
H. J. Ryan.
Frederick Bedell.

BELNAP, LA MONTE J., District Engineer, Bullock Electric Mfg. Co., 402 Merchants Bank Building, Montreal, Que.
Alfred Collyer.
R. B. Owens.
R. S. Kelsch.

BEE, WILLIAM G., Superintendent Auto Battery Department, Edison Storage Battery Co.; residence, 875 Bloomfield Ave., Glen Ridge, N. J.
T. A. Edison.
J. W. Aylsworth.
R. A Fliess.

BENJAMIN, EDGAR BRYANT, Assistant Engineer, Ideal Electric Contracting Co.; residence, 399 East 78th St., New York City.
S. W. Ashe.
Samuel Sheldon.
S. Aylmer-Small.

BERG, GEORGE HEWES, District Manager, Bullock Electric Mfg. Co., 262 Washington St., Boston; residence, Medford, Mass.
F. G. Bolles.
J. L. Hall.
R. T. E. Lozier.

BERGEN, OTTO, Engineer in charge of Generating Station, British Columbia Electric Railway Co., Goldstream, B. C.
Wynn Meredith.
K. G. Dunn.
G. W. Tripp.

BERRY, EDGAR HENRY, Chief Draughtsman, C. W. Hunt Co.; residence, 2d St. near York Ave., New Brighton, N. Y.
C. H. Machen.
J. Martin.
F. Martin.

BIEBEL, HERMAN MATTHEWS, Designing Electrical Engineer, Western Electric Co., Chicago, Ill.
A. D. Du Bois.
H. R. King.
H. H. Wait.

BISSELL, GEORGE WELTON, Professor of Mechanical Engineering, The Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.
B. S. Lanphear.
W. S. Franklin.
D. C. Jackson.

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George Hafer, Jr.
R. W. Pope.

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P. Junkersfeld.
E. Schildhauer.

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W. C. Fish.
F. P. Cox.

BRETT, JAMES A., Director and General Manager, Electrical Installation Co., 1517 Monadnock Building, Chicago, Ill.
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B. J. Arnold.
R. W. Pope.

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P. W. Davies.
J. A. Campbell.

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E. E. Boyer.
R. W. Pope.

BROUGHTON, JAMES RUSSELL, Station Foreman, The Power Co., Norris, Montana.
M. E. Buck.
P. N. Nunn.
W. H. Williams.

BROWN, THEODORE J., Traveling Salesman, General Electric Co., 200 Summer St., Boston, Mass; residence, 48 Deering St., Portland, Maine.
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S. B. Paine.
C. B. Burleigh.

BUSH, ARTHUR RICHMOND, Engineer, General Electric Co., Boston; residence, 51 Lexington Ave., Cambridge, Mass.
C. L. Edgar.
S. B. Paine.
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BURKHOLDER, CHARLES IRVINE, Electrical Engineer, General Electric Co.; residence, 108 Park Place, Schenectady, N. Y.
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D. C. Jackson.
E. B. Raymond.

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H. B. Spencer.
C. M. Green.

BURSCH, WILLIAM OSCAR, Assistant Foreman, Testing Department, General Electric Co.; residence, 5 City Hall Square, Lynn, Mass.
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F. P. Cox.

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G. W. Knox.
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E. L. Morley.

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C. B. Burleigh.
C. L. Edgar.

CHEYNEY, ALGERNON ROBERTS, Station Superintendent, The Philadelphia Electric Co., 26th and Callowhill St. Station; residence, 925 N. 42d St., Philadelphia, Pa.
J. M. Eglin.
W. C. L. Eglin.
G. N. Tidd.

CLARK, CHARLES WESTON, Agent, General Electric Co., Claus Spreckels Building, San Francisco; residence, Berkeley, Cal.
F. F. Barbour.
E. E. Boyer.
C. L. Cory.

CLAYPOOLE, CURTIS, Estimating and Superintending Construction work, The Electric Supply and Construction Co., 1457 Neil Ave., Columbus, Ohio.
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F. A. Caldwell.
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F. P. Cox.

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C. L. Edgar.
S. B. Paine.
C. B. Burleigh.

CRAWSHAW, JULIEN JEWET, Superintendent of Exchanges, Bell Telephone Co. of Missouri, 47 Telephone Building; residence, 4104 Flad Ave., St. Louis, Mo.
Gerard Swope.
H. H. Humphrey.
Henry Rustin.

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S. L. Foster.
S. L. Naphtaly.

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B. N. Jones.
F. A. Scheffler.
R. W. Pope.

CURRIE, HARRY ALLAN, Electrician, Brooklyn Heights R. R. Co.; residence, 87 South 9th St., Brooklyn, N. Y.
J. D. Keiley.
Samuel Sheldon.
S. W. Ashe.

CUTLER, ELIHU HERBERT, Manager, The Elektron Mfg. Co., 84 Westminster St., Springfield, Mass.
F. B. Smith.
Joseph Sachs.
W. B. Mulligan.

DAVIS, CHARLES BRIDGE, Local Manager of Boston Office, General Electric Co., 200 Summer St., Boston; residence, Lexington, Mass.
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WAGENHALS, EDWARD T.,	Superintendent, Trenton and New Brunswick R. R. Co., Trenton, N. J.	E. C. Boynton. B. L. Baldwin. R. W. Pope.
WARD, CHARLES ARCHIBALD,	Engineering Apprentice, Westinghouse Electric and Mfg. Co.; residence, Grant Boulevard, Pittsburg, Pa.	S. M. Kintner. Harris J. Ryan. R. W. Pope.
WARDER, WALTER JAMES, JR.,	Designing Electric Engineer, Western Electric Co., 242 So. Jefferson St., Chicago, Ill.	H. H. Wait. P. B. Woodworth. E. P. Warner.
WEBSTER, DWIGHT EDWARD,	Engineer and Salesman, Westinghouse Electric and Mfg. Co., Mountain Electric Co., Denver, Colo.	P. M. Lincoln. T. P. Gaylord. C. F. Scott.

WELLS, JOHN ALLEN,	Head of Marine Test, Testing Department, General Electric Co.; residence, 134 Barrett St., Schenectady, N. Y.	H. P. Freund. N. L. Rea. R. N. Williams.
WENTZ, ROBERT FILMORE,	Mechanical Designing and Constructing Engineer Gen. Elec. Co., Nazareth, Pa.	George B. Dusinberre. H. B. Coho. E. M. Tingley.
WHITAKER, JOHN SANBORN,	Constructing Engineer, General Electric Co., 200 Summer St., Boston; residence, 34 Stanley St., Dorchester, Mass.	C. L. Edgar. Sidney B. Paine. Chas. B. Burleigh.
WHITE, HAROLD E.,	Designing Engineer, General Electric Co., Schenectady, N. Y.	F. B. Corey. L. C. Marburg. V. D. Moody.
WHITE, WILLIAM WESLEY,	Electrical Draughtsman, The William Cramp and Sons Ship and Engine Building Co.; residence, Thorps Lane, below Wister St., Germantown, Philadelphia, Pa.	L. C. Brooks. Arthur J. Rowland. Chas. J. Dougherty
WHITEHOUSE, LOUIS CAMMANN,	Student, Stevens Institute of Technology, Hoboken, N. J.; residence, New Brighton, N. Y.	A. F. Ganz. W. E. Geyer. R. W. Pope.
WIARD, JOHN, BULKLEY	Assistant Engineer, General Electric Co.; residence, 11 Shepard St., Lynn, Mass.	W. C. Fish. Elihu Thomson. Harold B. Smith
WILSON, JAMES A.,	General Electric Co., 200 Summer St., Boston, Mass.	C. L. Edgar. Sidney B. Paine. Chas. B. Burleigh
WOODROOFE, WILLIAM TURTON,	Dynamo Tender, The British Columbia Electric Railway Co., Ltd.; 1423 Georgia St., Vancouver, B. C.	W. Meredith. K. G. Dunn. R. W. Pope.

Total, 211.

This, I believe, is the high-water mark:

The following Associates were transferred to the grade of Member:

Recommended by Board of Examiners, March 13, 1903.

FREDERICK DARLINGTON, Consulting Electrical Engineer, Stanley Electric Mfg. Co., Gt. Barrington, Mass.

S. E. JOHANNESEN, Electrical Engineer, Westinghouse, E. & M. Co., Pittsburg.

M. VON RECKLINGHAUSEN, with George Westinghouse, 510 W. 23d St. New York.

ROBERT ROBERTSON, Firm of Strain & Robertson, Consulting Engineers. Glasgow, Scotland.

WILLIAM ESTY, Asst. Professor of Electrical Engineering, Lehigh University, Bethlehem, Pa.

The Board of Directors this afternoon had the pleasure of receiving a communication from one of our esteemed members, and one of the oldest, who has stood by the INSTITUTE through thick and thin, Mr. C. O. Mailloux, enclosing his check for $1,350, as a further contribution to the library of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. $1,000 of this sum is to be set aside as a fund, the interest of which is to provide for keeping up the sets of transactions which Mr. Mailloux has furnished, and which are subscribed for by the year, and the remainder is to be used in purchasing other sets, binding, etc.

THE PRESIDENT:—We are pleased to have with us this evening a guest from the Old World, Dr. Adolf Franke, Technical Director of the Siemens & Malske Company. Dr. Franke has put into service the longest Pupin telephone circuit which has been installed, 450 miles from Frankfort to Berlin. Dr. Franke states that only a small proportion, one-quarter, of the usual amount of copper was required, and as Mr. Martin expressed it, the line talks like a parrot. I am pleased to introduce Dr. Franke to the INSTITUTE and shall be pleased to have a few words with him

DR. FRANKE:—Mr. President and Gentlemen: I thank you very much for your kind reception, and I beg that you will excuse me if I cannot express my thanks in a better manner—my English is very imperfect.

A paper read at the 176th Meeting of the American Institute of Electrical Engineers, New York, April 24th, 1902.

TENDENCIES OF CENTRAL STATION DEVELOPMENT.

Introduction by President Scott.

If we were to go back to its very beginning, we should probably find that there were two elements which marked the dawn of civilized life, and which may be traced through all its development. One of these was the use of implements—probably a club and a sharp stone were the earliest tools. The other was coöperation for a common purpose—probably protection against a common enemy was the first incentive.

These two elements: namely, the use of tools, or more particularly the adaptation of the materials and forces of nature to accomplish results beyond the power of the individual; second, coöperation followed by specialization, in which individuals of different abilities act together, each one doing the share for which he is best qualified, may be traced through the various stages of development, prehistoric, ancient and modern. The development along these lines has been especially marked during the past century and notably the past generation. The interrelation between these two elements is notable. The use of tools and of machinery, together with the generation and the application of mechanical power have brought about a new order of things in the relations between individuals and the relations between nations. Manufacture and commerce have passed through a wonderful evolution. Social conditions have changed. The whole United States is scarcely larger as measured by the time-table for travel or the rates for transportation of freight than was the little island of England a century ago. In the time of Dr. Johnson the mind of one man was presumed to be able to encompass the whole of human learning. The change which has taken place in learning is indicative of the broadening and the special-

izing which characterizes every department of modern life—intellectual, industrial, commercial, social.

Society is not a mere aggregation of individuals; is it not simply a mass of men, but it is a vast unit. Men are not independent; they are correlated and interdependent. The fundamental condition for such a state is material. Just as a factory is essential for workmen who are to build dynamos or locomotives, so do the material facilities of our modern cities—their buildings, their street cars and elevators, their telephones, their water supply and sewage systems, their lighting and power systems—constitute the factory, the tools, the mechanism which makes our modern life larger and more effective than that of the olden time.

I think of no institution which is so completely representative of the modern development of those early beginnings of civilization whose development we have been tracing, than is found in the Central Station. In it is found an application of natural forces on a most comprehensive and diversified scale. Its very existence is dependent upon social coöperation; and in turn it contributes to the convenience and the comfort and the effectiveness of a whole community.

Electricity is a unifying agent. As a science its theory promises to be the secret which will bring together the mysteries of chemical affinity, of magnetism, of light, of gravitation. As an engineering force it is on most intimate terms with every branch of engineering, aiding, unifying and simplifying. I repeat an illustration which I once used before the INSTITUTE:

> "A generation ago it would have defied the imagination to discover any natural connection between such widely different agents as horses pulling street cars, locomotives drawing elevated trains, gas lighting houses and streets, water operating elevators, stoves heating and cooking, and engines of every sort and class doing a hundred kinds of work. But all of these and many others are in common being superseded by the electric current, which does not merely replace but develops, expands and transforms. It is notable that all of this varied service . . . could be supplied with current from a common universal system."

The Central Station system in itself is typically representative of coöperation and combination in design, and construction, in the combustion of coal and the production of steam, the operation of engines and condensers, of dynamos and switches, of indi-

cating instruments and safety devices, of conductors and cables, and the operation of apparatus in substations and on the premises of a thousand customers. Each element is in a measure dependent upon all the others. The reliability of the Central Station commends in highest terms the ability and success of the modern engineer.

The following statement has been given me to-day: "The Edison system in New York City as a whole has never been without current. There have been several accidents, including the fire at the old Pearl street station in 1890, which have temporarily affected a district, but since 1893 there have been no interruptions of service on the system. On March 31, 1903, the New York Edison Company, on Manhattan Island, was supplying current to 26,000 customers a total equivalent in 16-candle power lamps of 2,391,431."

The Central Station system is an evolution—an evolution as a whole—an evolution in its elements. In 15 or 20 years many of its elements have come into existence, while others have undergone most radical changes—boilers, engines, generators, switchboards, cables, safety devices, rotary converters, lamps and motors—and in addition to the apparatus there has been the growth of the great system by which they constitute a single whole.

Progress has not ceased—its acceleration continues. The Central station will in itself increase its extent and its effectiveness. As electric power distribution in the factory has revolutionized methods and led to increased output and reduced cost of products, so electric power distribution in the city revolutionizes the customs of the people, and is a vital factor in advancing civilization.

A paper read at the 176th Meeting of the American Institute of Electrical Engineers, New York, April 24, 1903.

ECONOMICAL AND SAFE LIMITS IN THE SIZE OF CENTRAL STATIONS.

BY H. A. LARDNER.

Some of the considerations which induce companies to erect large central stations. The probable effect of steam turbine development on the size of generating units. Advantages and disadvantages of large central stations. Where several small stations replace one large plant the necessity for excessive engineering refinement ceases to exist.

In this day of gigantic engineering enterprises, one would be very conservative indeed if he placed any limit on the possible size of modern central stations. From the plans for extending some of the well-known plants, the engineers of the companies owning them apparently think they have not reached the limit either from the point of economy or of safety. I shall certainly not attempt to place any limits on the size of power stations, for each case must naturally be considered as a separate problem. However, I may call to your attention some of the considerations which induce companies to erect large stations, and give an opinion of the objections and disadvantages which attend their operation. There are many subjects which have an important bearing on the question and some of them will be discussed.

Territory to be Served.

If the territory is large and the system is to serve several villages or small cities with power for lighting or for railway purposes, one large station located conveniently for coal and water has a decided advantage, owing to economy in labor, lower cost of fuel, water and first cost.

Frequently the business in the individual towns would not be large enough to permit of an independent plant in each, and any risk of interruption to service is put up with because it is the best kind of service that such a community can support.

In fact, until the class of territory approaches that of our largest cities, the question of lower first cost and economy of operation must in general rule; for the size of station is not large enough to minimize those advantages or to demand the advantages of a service supplied by several stations, harmoniously designed and operated.

When the territory becomes similar to New York, Chicago, Brooklyn, Boston, etc., the large station has many claims for consideration. As the central stations now built in this class of territory are so much larger than those which have been erected elsewhere, we may confine our discussion to stations for the larger cities.

We may also exclude water power stations, as they must of necessity be located at the point of development or waterfall, and it is seldom the case that several plants can be built, each large enough to secure the maximum advantages of low cost and low operating expenses, as at Niagara.

System of Distribution.

The system of distribution which must be used, frequently has a direct bearing on the demand for a large station. Where the distribution pressure is low as in Edison three-wire 120-240 volt systems, there are few if any cities where a sufficient load can be found for a very large station without exceeding the limited zone of economical distribution at this pressure.

Where this system is in operation we find that the stations are generally of high first cost and too small to be operated economically. The location is necessarily chosen without regard to the water or coal supply, and the load factor is generally very bad, which adds to the expense of operation. As a temporary expedient at least, rotary converters, transformers and high pressure cables have found a place for connecting together the direct current stations and thus enabling them to exchange power and considerably improve their load factors.

For instance, in New York City the Duane Street Station of the New York Edison Company, with its heavy day load of motors and early evening load of office buildings, has a very different shaped load curve from the 26th Street station or the generating stations formerly located in 39th Street and 53d Street, which

delivered their principal service during the evening. However, the double conversion results in losses which should be saved, and still continues the use of uneconomical small stations.

The next step is to establish a large well-located alternating current station and feed the rotaries from the machines there installed. This method permits the use of the largest size of generating units, gives their attendent economies, and the demands of the various sections of a city coming at different hours of the day produces a better load factor.

The generating apparatus installed in the distributing or substations, as they may now be called, can be operated if desirable for one or two watches during the heaviest loads in their particular sections, and the combination undoubtedly results in greater economy. The existence of these substations with generating apparatus provides a certain amount of reserve or emergency power which can be called upon, and the danger of concentrating all the generating apparatus in one station is in a measure avoided. The fact of their existence also acts as an incentive to keep down the number of new generating stations and to build one alternating station large enough to meet the entire demands of the system, no matter how large that may be.

The use of the 240 volt incandescent lamp is much more common abroad than with us and while I am not able to comment on the relative merits of the lamps made at home and abroad, I do believe that a more insistant demand for a 240 volt lamp would be met by our manufacturers and result advantageously.

By the use of a three-wire system and 240 volt lamps, the advantages of 500 volt distribution in copper economy can be obtained, and the zones which can be served from any one station very considerably increased. It is an open question whether with this system of distribution the stations can be made large enough to be built for a fairly low first cost and operated at practically a minimum expense. There is a case in point in Boston, where the Boston Elevated Railway Company has a number of stations ranging from 1,500 to 4,000 k.w. and the results of operation are reported to be very low and comparable to the best results which have been shown in much larger stations.

The alternating current system of distribution with primary voltage of 2,200 volts and over, has the ability to serve a very extended territory. With this system of distribution, the question of one large station should not be so important, as the load can probably be divided between two or three stations, each

large enough to be economical, and by the use of trunk cables they may aid one another in handling the load and add materially to the safety and continuity of the service.

SIZE OF UNIT FOR MOST ECONOMICAL OPERATION AND FLOOR SPACE.

From the compilation of Mr. C. D. Gray in the Journal of the Franklin Institute, October, 1901, I give the results of tests on compound Corliss condensing engines. The best results published, and one near the average, are given for several different sizes.

Pressure.	Vac.	I.H.P.	Steam.	Authority.
155		1950	12.5	Thurston; *Science*, Oct. 1, 1897.
150	26.9	1713	12.3	Barrus; "Engine Tests."
123	25.6	1592	13.5	Thurston; A. S. M. E., 15–839.
133	25.2	1539	14.1	Barrus; "Engine Tests."
126	27.0	1107	14.1	Barrus; "Engine Tests."
120		1018	13.3	Barrus; A. S. M. E., 15–839.
117		1001	16.3	Sibley Journal, 8–393.
151		997	12.8	Barrus; A. S. M. E., 14–1340.
112		709	15.1	Stone & Webster; *S.R.J.*, Aug., 1898.
144	25.2	741	13.2	Barrus; "Engine Tests."
159	25.4	595	12.7	Dean; A. S. M. E., 16–169.
90		548	13.5	Thurston; *Elect. World*, Jan. 5, 1901

It will thus be seen that under proper conditions of design and operation, very good comparative results can be secured with units much smaller than those installed in the large stations in New York.

The published guarantees for the steam consumption are as follows, in these stations:

Station.	Pressure.	Vac.	I.H.P.	Steam.
The New York Edison.....	175	27	5500	12.5
Manhattan Railway	150	26	8000	13.0
Metropolitan Street Railway	160		4500	13.14

That part of the cost of labor for engine operation, which varies with the size, amounts to but a small portion of the total operating expenses; and although the larger the unit, the smaller the item becomes per h.p. hour, it is relatively of little importance, except in very small units.

The question of floor space required for reciprocating engines of different sizes demands the largest units practicable.

The vertical space required by an engine is provided more cheaply than the floor space, and as the requirements are of three dimensions the floor area should not increase proportionally

with the size of the unit. Again, the aisle space must be practically the same for engines differing in size by large percentages.

In spite of these facts, the floor space in engine rooms per h.p. appears to be affected more by the type of engine used and the judgment of the designer than by the size of the unit. The Edison station with engines of 5,500 h.p. normal rating requires only about one-third of a square foot per h.p. and the Metropolitan with 4,500 h.p. units one-half of a square foot per h.p. against the 8,000 h.p. units in the Manhattan station, with an area of .55 of a square foot per h.p.

It therefore appears that economy of operation and in floor space may be made entirely too much of in discussing the advantages of large units, although with similar design and type of machinery the large units undoubtedly have some advantages, provided the station is large enough to require a sufficient number of units to permit of economical loading.

The following table will give some published data about the engines in the New York Edison, Manhattan Railway and Metropolitan stations:

Engines.	Metropolitan.	Manhattan.	Edison.
Number	11	8	8 installed 16 ultimate
H.P. each normal rating	4,500	8,000	5,500
H.P. each maximum rating	6,600	12,500	8,000
Aggregate rated H.P.	49,500	64,000	88,000
Aggregate maximum H.P.	72,600	100,000	128,000

From the large number of units, we may assume that these are the largest machines the manufacturers cared to produce.

Larger engines have been built for use aboard ocean liners, and as conditions are in many ways much more severe aboard ship than on land, it should be possible to have still larger units if central station engineers really demanded them. The following characteristics are given of the engines of the Kaiser Wilhelm der Grosse:

Two engines, triple expansion, four cylinders; diameters, 52, 89.7, 96.4, 96.4 ins.; stroke, 68.8 ins.; piston speed, 885 ft. per minute; revolutions, 77+; steam pressure, 178 lb.; rated h. p. of each engine, 15,000.

The steam turbine has now been perfected so that many plants are ordering them, and in a year or so a great many will doubtless be in operation.

The turbine presents some characteristics which will, I believe, affect our decision in regard to the arrangement and number of stations for a given system. Although much has been written of them lately, they may be briefly alluded to here.

This type of prime mover has decided advantages over reciprocating engines for driving many classes of electrical machines, as it gives ideal conditions for the parallel operation of alternators and synchronous apparatus on account of its uniformity of angular velocity. We are assured that steam turbines run together in parallel with the same facility as hydraulic turbines have always done. It is well known that many difficulties in the operation of 60 cycle apparatus disappear when the supply of power is from water wheels, and if the steam turbines are to help us in this respect it will be a great point in their favor.

There is every reason to believe that the use of superheated steam with turbines will be a comparatively simple matter, as the turbines will have no internal rubbing surfaces or cylinder oil. Exhaust steam from turbines, being free from oil, may be condensed and returned to the boilers, and this will be an important consideration in many plants now purchasing city water for boiler feed and which find the extraction of oil too difficult and expensive to permit the water being used a second time.

Due to the high speed at which turbines are operated, direct current machines seem to be ruled out on account of commutator troubles.

Perhaps the greatest advantage of the turbine is its economy of floor space. In the paper presented by Mr. Sniffin, before the American Street Railway Association of last year, the statement is made that the Westinghouse-Parsons turbine requires about 80 per cent. of the space needed for the vertical and not over 40 per cent. of that wanted for the horizontal engine. This statement is based on a station layout with a clear space of seven feet in all directions between machines. This type of turbine being horizontal, requires less head room and consequently a cheaper building by a considerable amount than the vertical engine. Mr. Sniffin's curves place the required building capacity for turbines at about 50 per cent. of that for vertical engines.

The Curtiss turbine of the General Electric Company is of the vertical shaft type and while it requires more head room than the Westinghouse-Parsons machine, is very economical of floor space. The following table gives the principal dimensions of some of the sizes which are now being built.

CURTISS TURBINES AND GENERATORS.

Size.	Height.	Diameter.	Floor Space.	R.P.M.
500 k.w.	12′ 2″	7′ 8″	46.2 sq. ft.	1800
1500 k.w.	16′ 10″	10′	78.5 "	900
3000 k.w.	22′	14′	154. "	600
5000 k.w.	27′	14′ 10″	173. "	500

WESTINGHOUSE-PARSONS TURBINES AND GENERATORS.

Size.	Height.	Dimensions.	Floor Space.
400 k.w.	7′ 6″	19′×5′	95 sq. ft.
1000 k.w.	8′	43′×8′	344 "
5500 k.w.	15′	50′×12′	600 "

For comparison, the following is the floor space required by the vertical cross-compound condensing engines of a well known maker. The figures include the space required for an alternating current generator between the frames.

Size.	Dimensions.	Floor Space.	R.P.M.
500 k.w.	15′×22′	330 sq. ft.	120
1000 k.w.	21′×24′	504 "	110
1500 k.w.	22′×28′	616 "	100
2500 k.w.	23′×32′	736 "	90
3000 k.w.	23′×34′	782 "	75

The height would in all sizes exceed that of a similar size of vertical turbine.

The steam consumption guaranteed for the above mentioned Curtiss turbines are attractive, especially at light loads. The figures are given in dry steam per k.w. hour; and for purposes of comparison with results per i.h.p. they have been reduced by assuming an efficiency for generator and turbine of 85.

Size.	Pressure.	Vacuum.	Steam per k.w.h. Full Load.	Steam per k.w.h. Half Load.	Lb. per I.H.P. Full Load.
500	150	28	20½	23	13
1500	150	28	20½	22	13
3000	150	28	20½	21.5	13
5000	150	28	20½	21	13

The simplicity of the turbine leads us to believe that the high efficiency will not decrease with use nor by reason of lack of adjustment. The method of guaranteeing the efficiency of generators and engines together will permit this guarantee to be checked more closely than has ever been possible with large engines and generators, on which separate guarantees have been given.

I believe that the cost of labor for engine operation will be considerably cheapened with the turbine, and this and the other advantages shown should greatly reduce the necessity for very

large units. If, therefore, steam turbines are to make the operation of smaller stations (with a suitable number of units to handle the load economically) equal in efficiency to some of the largest plants now installed, it will be advantageous in many cases to install several stations in place of one, and obtain all the saving n distribution and safety against shut-downs that go with such an arrangement.

There are, of course, certain cases where a location cannot be secured convenient to coal and water in more than one place, but these cases are rare. Boston, New York, Chicago and nearly all our largest cities afford opportunities for securing a number of sites, all practically of equal desirability so far as facilities for getting supplies are concerned.

ADVANTAGES AND DISADVANTAGES OF LARGE CENTRAL STATIONS.

The advantages may be summed up from what has been previously said, and consist mainly of the following:

The location of the station on the one most suitable site for the coal and water supply.

The reduction of floor space by the use of large units.

The economy of fuel secured by the use of large generators and engines.

The economy of labor and general superintendence secured by the use of large units in one building.

The saving in first cost effected by the installation of a large station with large units.

The economy of operation secured by serving many sections of a city with different hours of maximum demand from one station, due to the better load factor obtained.

The installation of a large station presupposes supplying a very large territory from one source, and in order that the coal and water supply may be convenient, the chosen location is generally much farther from the load than when it is divided among several plants. This involves a greater expense for a distribution system, although this may be minimized by the installation of high potential current or by local conditions.

The economy of floor space by the use of large units will always be an important consideration where land is valuable, but the economy in this direction with the steam turbine may lead the designer of the future to give less consideration to this point.

The added economy of fuel, labor and general supervision in large units will also be reduced somewhat even with the large

turbine units, and the first cost of the machines themselves will undoubtedly decrease per unit capacity with increase of size. However, the reduction in cost of turbine generator installation from the prices now paid for generators and slow speed reciprocating engines should be considerable and permit smaller units than are now feasible. This will undoubtedly be true after development charges have been cared for.

It is a question whether there is any saving in the first cost in the installation of very large stations, except in prime movers and generators. The construction of double and triple decked boiler rooms, long coal handling apparatus and coal pockets high above the ground, involves heavy expenditures without compensating advantages. It is probable in the case of some large stations in this city that they could have been built to half their capacity as cheaply per unit as to the ultimate size. The size of the units in either case would probably have been the same.

The principal disadvantage of the very large station is the danger to a system if the disabling of the station leaves the company without a source of power, or takes away a larger portion of its supply than can be cared for by overloading the remaining plants. It is with this point in view that I have attempted to bring out all the points which may make smaller stations worthy of more consideration than they frequently get.

The stations in this city are wonderful examples of good design in all features which tend to make them reliable and free from dangers of serious breakdown and interruption of service. As one designer said in describing his station, it was built to withstand anything but an earthquake or a bombardment. While it may be possible to build such a station, I do not believe that there has been a single station built, and I do not look to see one, which is free from weak points capable of causing interruptions. These features are apparently unavoidable, and while accidents due to them may not do any serious or expensive damage, they may render the building untenantable to employees or to enough of them to cause an interruption to the service.

The recent breakdown at the station of the Niagara Falls Power Company is an instance in point, and while such occurrences have been rare, the one in question left Buffalo without Niagara power for eighteen hours, and part of the Niagara Falls district was without power for nearly as long. I do not think an officer of a large company will look on a like condition without considerable apprehension. The trouble at Niagara is reported

to have been started by a lightning storm which resulted in destroying the cables leading across the bridge from the generator room to the transformer house. Now that it is over, engineers say that there should have been two routes for these important cables, and a number of suggestions may be made to avoid a repetition of the difficulty.

Shut-downs have occurred in some other large stations during the experimental periods of their operation, and while these were doubtless due to poor material or workmanship that had not been weeded out, the failure of material or errors of employees may occur after years of use, and the results are likely to be the same.

Instances occur in this city where cables may be damaged by one cause or another, and the results would not be very different from the Niagara breakdown. Rheostats for the fields of generators may be the weak point in another station; switchboards exposed to flying pieces in another. These weak points can generally be corrected, but the fact is that they now exist and are in my opinion possible sources of trouble.

I do not wish to go on record as advocating a greater refinement than is commercially justifiable, and perhaps this point has been reached by the designers of the large stations. The point I do wish to make is that smaller stations need not lack many of the advantages of the large ones, and with a number of them in place of one large plant, the necessity for excessive refinement ceases to exist.

A paper read at the 175th Meeting of the American Institute of Electrical Engineers, New York, April 24, 1903.

SAFETY DEVICES IN CENTRAL STATIONS AND SUB-STATIONS.

BY PHILIP TORCHIO.

A review of general principles followed in the design and arrangement of electrical apparatus of generating stations, transmission lines and sub-stations and a list of safeguards against break-downs and devices for localizing and clearing faulty elements of the system. Advantages of storage and reserve supply to ensure continuity of service to customers.

The importance attached by central station managers and consumers to the reliability of service has been brought to bear so strongly upon the designing engineers and manufacturers of high tension apparatus that the problem of safety has received, and is still receiving even in its details, the study of every engineer identified with high tension central station work. This applies not only to the designing but also to the installing and operating of central station apparatus.

What has been achieved is therefore the work of many men, of many experiments, often failures and costly trials and worries; and even now it cannot be said that the problem has found its final and general solution. Therefore I shall approach the subject along broad lines, so as to invite discussion and suggestions on the characteristic features aiming to increase the factor of safety or to insure continuity of service.

High tension transmission systems may be overhead or underground, or composite overhead and underground. For moderately high voltages, up to 15,000 volts, the transmitted current can be generated directly or can be obtained from step-up transformers. For higher voltages step-up current only has been used up to the present time. All these different conditions create special

requirements for each individual system. In this brief review no attempt has been made to enter into special details particular to any individual case. What follows applies more or less generally to all systems.

Mechanical Reliability.—In this connection no attempt has been made to deal with the feature of mechanical reliability of the generating systems, though it is as important for the mechanical equipment to be safe and reliable as it is for the electrical equipment to be so. In fact the general principle of subdivision and independence of different generating units may be considered to find its application throughout,—from coal supply at the boilers, through the mechanical and electrical equipment at station and transmitting lines, to the receiving substations.

Electrical Reliability.—Proceeding from the generating station to the transmission line and receiving substations, we find the following characteristic features more or less generally adopted o considered desirable from the aspect of reliability of service. Some of the safeguards given in the list appear perhaps as unnecessary and expensive refinements, and probably they would be so for a large number of cases where continuity of service may not be considered absolutely essential. In a large situation, for instance the lighting and power of a large city, the conditions are different; and if for these conditions safety cannot be obtained in any other manner, these refinements become of paramount importance.

GENERATING STATION.

1. Installation of storage battery on field exciter bus, at generating station.
2. Equipment of reverse current relays and circuit breakers on exciter generators.
3. Equipment of overload relays with time limit and circuit breakers, on motors of motor-generator exciter sets.
4. Separation and mechanical protection of generator leads of different generators. Also proper insulation and protection against capacity discharges of cable leads.
5. Connection of each generator to bus bars by means of two oil switches in series, preferably arranged to close independently and open at the same instant.
6. Sub-division of bus bars, in different sections, enabling operation of generators in different groups. Also selector switches on each generator, enabling the same to be operated on at least two sections of bus bars.

7. Tie connections between different sections of bus bars, enabling us to make, if desired, combinations of different sections or even one common bus bar.
8. Overload and reverse current relays on generator switches, these being connected to signal lamps until they have proven their reliability for actual tripping of main switches.
9. Selector switches on feeders providing means of connecting each feeder to at least two sections of bus bars.
10. Duplication of oil switches on each feeder circuit, preferably arranged to close independently and open at same time.
11. Overload relays on each feeder, with a variable time limit, in inverse proportion to the amount of current.
12. Separation of all wiring and busses inside the station by means of ducts, fireproof septums and grooves in walls, and proper protection against capacity discharges, by the use of good glass or porcelain insulators.
13. In connection with very high voltage step-up transformers, provide low tension synchronizing busses for generators and switches on the l.t. side of step-up transformers, thereby avoiding synchronizing on the h.t. side of transformers, or closing of h.t. switches on dead transformers.
14. Avoid installation of single pole main switches for each phase of the circuit, and also synchronizing with one pole switch closed and synchronizing transformer across the gap of the other pole switch.

TRANSMISSION LINE.

15. Duplication of transmitting lines to important centers of distribution, selecting if possible different subway routes, or independent transmission lines.
16. Mounting of suitable end boxes on ends of cables at all terminals. Also possible equipment of spark arresters on each end of underground cables.
17. Protection of underground cables in ducts by the use of good fire-proof material.
18. Protection of cables in manholes, using preferably separate manholes for high tension cables, with asbestos or iron covers on each cable, etc.
19. Protection of lead sheath of cables against electrolysis, either by laying cables in vitrified ducts and rubber cushioned racks in manholes, thereby making the cable insulated from ground along its route, or laying heavy bare copper

wires along the route of cables and connecting solidly to their lead covers in each manhole, these wires providing a secure metallic path for the current, which leaves the cable sheaths to return to the grounded bus at the railway station via the wires suitably connected to the railway return feeders.

20. Protection of transmitting and receiving stations operating overhead transmitting lines by improved lightning arresters.

21. Grounding of neutral of three-phase transmission lines for very high voltages. (General practice in the California transmission plants.) In the case of very high voltages, this grounding seems a necessity.

22. Possibly grounding of neutral for lower voltages and underground cables. (This is done in several places, as for instance, in Chicago, on the 2200 volt 3-phase, 4-wire, 60 cycle system, as well as on the 9000 volt 3-phase, 25 cycle star-connected system). From the point of view of reducing strains on insulation, this grounding of neutral seems unnecessary for moderate voltages, though it could be made use of for locating accidental grounds on the system, and in indicating and eventually disconnecting the affected feeder, which would be troublesome to locate on a system without grounded neutral and operating several feeders from same bus bars.

23. Avoid operation of high tension lines at different frequencies when lines are mounted on same pole line. This to avoid doubling of strain on insulators when two wires of different lines become crossed.

SUBSTATIONS.

24. Separate lines entering substations should preferably be operated independently, laying out independent h.t.. busses and transforming apparatus on each line, the transformed current being delivered either to a common set of bus bars or to independent sets of bus bars, if the service will allow of this subdivision. In rotary substations, while the rotaries operate in parallel on the d.c. side, they can be fed from independent h.t, lines not operated in synchronism. This allows feeding each substation from different groups of generators at the generating station, or even from different generating stations. In the case of a.c. stations with transformers

feeding into a common secondary set of bus bars, the primary lines must necessarily be operated in parallel, and therefore from same bus bars at the generating station. This prevents us from attaining the advantages of duplicate lines and independent sources of supply, as in the case of rotary substations. For this reason, in a.c. systems of secondary distribution, as extensively used in waterpower plants, the adoption of independent groups of generators and independent feeding lines to important centers of distribution is not common. In important cases it may be advantageous to subdivide the customers' supply on different circuits fed from independent lines and transformers operated from different sources of supply. The New York Edison Company operates at present the generators at its Waterside Station in two independent groups and whenever a substation has more than one rotary converter in service, the several rotaries are divided among different feeders, fed from different groups of generators at the generating station. The rotary converters being operated in parallel on the d.c. side, the distribution of loads between different feeders and consequently between groups of generators is easily and perfectly accomplished. This distribution is regulated by the system operator at the station, who instructs each substation how to subdivide the loads among the rotaries. The system is laid out to still further subdivide the groups of generators, if the further addition of generators will make it desirable.

25. Receiving lines should be equipped with oil switches and overload relays with variable time limit in inverse proportion to amount of current. When more than one line is feeding a common h.t. bus or independent transforming apparatus operating in parallel on the l.t. side (for instance, rotary converters), each line should also be equipped with reverse current relays, with variable time limit in inverse proportion to the amount of current, the time limit for these relays being a fraction of the time for the overload relay. Reverse current relays without time limit are too sensitive to momentary irregularities on h.t. system and cause trouble on this account.

26. Inside the substations all h.t. wiring and construction should be laid out along the same lines mentioned in case of generating station. Also, the low tension apparatus

and connections should be properly laid out, avoiding crowding and crossing of cables, keeping cables of different polarities separate, and protecting them by means of ducts, septums and pipes as much as possible.

26a. On very high voltage receiving stations, the closing of h.t. switches on transformers subjects them to heavy strains which can, in most cases, be avoided by making alive the transformer from the low tension side, if the common bus bars are already fed from another set of transformers. In case of a single set of transformers, it may be advisable to leave the high tension side of transformer closed all the time, especially in water power plants.

27. For protection of lines from overloads or short circuits on transforming apparatus of large capacities, oil switches with overload relays should be considered preferable to h.t. fuses. The switches should be of proper capacity and should be equipped with locking relays for overloads, exceeding the safe breaking capacity to avoid blowing up the oil switch. The breaking capacity of an oil switch will to a great extent depend not only on the character of load, but also on the amount of power back of the short circuit.

28. Compound wound rotary converters and eventually also plain shunt wound rotary converters operated in parallel on a common d.c. bus should be protected by some speed limit device to trip the a.c. and d.c. circuit breakers on the rotary, when speed exceeds the normal by a certain fixed percentage. The sample here shown is a speed limit device developed by the company with which the writer is connected, in conjunction with a firm which manufactures measuring instruments; adopting their standard mechanism for speed indicators.

29. It is desirable to protect the d.c. side of all rotary converters with circuit breakers to operate in connection with the speed limit device above mentioned, and also in connection with a reverse current relay on the d.c. side of the rotary. This reverse current relay should be equipped with a variable time element in inverse proportion to the amount of reverse current; d.c. overload relays seem to be unnecessary.

30. All relays at different points of the system and their time elements must be properly adjusted, to operate the differ-

ent circuit breakers in the proper order, so that if a trouble is once cleared by the opening of certain circuit breakers, the other relays reset themselves in the normal position, leaving the rest of the system in operation.

31. Emergency connections between different generating stations are considered desirable and have found favor in connecting different water power plants and also in connecting large generating stations in the same city, as in New York.

32. Of first importance in a lighting situation in a large city is the equipment of storage batteries at every substation. One large New York company, for instance, has installed or under contract twenty-two 8,000 ampere hour 135 volt batteries, and more may be installed in the future.

33. In closing this list of safeguards, it may be added that in all high tension work, great care should be used in applying tests to the apparatus, especially in making insulation tests on generators, cables, line and transforming apparatus. Breakdown tests can be made on samples, but it is unwise to strain unnecessarily the insulation of the complete plant near the breakdown point. Close inspection of the installation will finally give more satisfactory results than loose inspection and severe tests.

NOTE.—During the reading of his paper, Mr. Torchio referred to a type of lightning arrester tested in Europe and designated as a lightning arrester of the series type. The description of this lightning arrester was presented at the meeting of the Italian Electrotechnical Society on January 20, 1902. The theory of the lightning arrester is not clearly explained by the inventor, although seemingly the apparatus gives good results. It is claimed that the presence of this apparatus on lines equipped with standard lightning arresters causes the latter arresters to cease discharge at any slight atmospheric disturbance as noticed previous to the installation of the series type lightning arrester.

This is an important feature from the fact that the lightning arrester does not wear out on account of slight static discharges which are always present on transmission lines, and which wear out the apparatus if kept in constant use. By freeing the lightning arresters from this constant wear they would be in better condition to do the work when the emergency arises.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York, April 24, 1903.

MULTIPLE VERSUS INDEPENDENT OPERATION OF UNITS AND CENTRAL STATIONS.

BY PETER JUNKERSFELD.

Practical difficulties encountered in the operation of central station systems. A statement of the troubles that beset the electrical engineer on the many different links between coal-pile and translating device. An argument for independent or sectional operation of every central station system.

The tremendous development in the application of electricity has opened immense fields, which to central station men are continually presenting new problems and graver responsibilities. In all centers of human activity the extended use of electricity is closely associated with the success, well-being and comfort of the public, as well as of individuals. The home, club and hotel; the office, factory and mercantile establishment; the church, theatre and public place; the streets at night, and the great transportation systems,—all these are thrown into confusion and disorder on even a slight interruption in the supply of electrical energy.

All members of the INSTITUTE are more or less familiar with central station systems, the principal features of which, in the larger cities at least, have been developed along fairly uniform lines. The many practical difficulties of operation, largely influenced by local conditions, are matters of vital importance from both commercial and engineering standpoints. The object of this paper is to call attention to some of these difficulties, with the hope that this will result in a full and profitable discussion.

The direct current systems of generation and distribution for

lighting and general power, and for street railway work, are inherently somewhat elastic. Satisfactory multiple operation of generating units, thus giving a high average station economy, was early accomplished. In large cities the adjacent systems supplied from different stations were gradually tied together, and resulted usually in a large network of interconnected mains supplied at points of greatest density of load by feeders from the nearest generating stations. The equalizing effect between different points of network greatly increased the stability of such systems, which are often further improved by the use of storage batteries properly distributed.

The quality and continuity of direct current service with this arrangement, has, in most cases, been very satisfactory. However, on account of the heavy fixed charges and losses in operating a large number of small generating stations—many with necessarily poor economy—the limitations in reducing cost of production were very serious indeed.

In the largest cities, having a rapidly increasing load, operating costs have been considerably reduced by alternating current generation, high potential transmission, and rotary converter substations. While these transmission and conversion systems have been developed and fairly well standardized as to general features, there is often still much to be desired in their operation. Systems operating with synchronous generating and converting apparatus and delivering current to the more elastic direct current network, are especially sensitive to any irregularity in the operation of the prime mover itself or in any of the transmission or conversion units. It is not to be understood that the central station service in large cities is less reliable than before, but that a peculiarly unfortunate feature has been introduced. This temporary disadvantage has in most cases been more than offset by decided improvements and safeguards affecting the continuity of central station service.

The primary cause of trouble may usually be traced to the failure or unsatisfactory performance of apparatus; the mistakes or the inattention of men handling apparatus; or mechanical injury and interference from some exterior source. Troubles of one kind or another, even with the best modern systems, are always possible on the many different links between coal-pile and translating device. In a large central station system supplying direct current, these links might be enumerated and troubles classified as follows:—

Mains and services.
Low tension feeders.
Substation apparatus.
High tension transmission lines.
Generator, prime mover and auxiliaries.
Steam supply.

Troubles in wiring or translating devices on consumer's premises are usually more directly under the control of the consumer than of the central station.

These different classes of central station troubles are all more or less liable to occur, but the prevalence of any one class or number of classes of trouble depends upon the character of the different installations, and on local operating conditions. In the discussion of these different classes of trouble the writer would, as a matter of illustration, refer to conditions in Chicago where all 25 cycle high potential transmission and direct current distribution is underground. In the outlying districts the 4 wire, 3 phase, 60 cycle distribution is overhead.

Mains and Services.—Formerly Edison tube was principally used for all underground mains. The more recent practice has been to use, largely, cables in conduit giving less trouble than the Edison tube, which is true also of services. However, miles and miles of the old tube mains are in service to-day, and must necessarily remain in service for years to come.

Any trouble, either on mains or services, is usually confined to a comparatively small area by the blowing of strips in the feeder junction boxes. The total amount of current that could be " pumped " into such a short circuit is limited by the drop in mains and feeders, at least back to the substation bus bars. Obviously, the duration of such a short circuit depends on the condition and relative carrying capacity of the " short " and the fuse strips back of it. The drop in mains may be such that it is impossible to deliver enough current to burn off the trouble or blow the fuse strips. These cases, while rare, are very annoying. Sometimes they will " clear " only to start again at an unexpected time, occasionally even making it necessary to remove junction box strips and thus cut out the troublesome section until permanent repairs can be made.

Low Tension Feeders.—On account of the larger carrying capacity the energy delivered on short circuit is very much greater in feeders than in mains. The total length of conductor in feeders being much less than in mains, the number of troubles

with equally good construction are correspondingly less. Furthermore, instead of tubes, cables have been very generally used for several years. This improved construction also makes the actual number of feeder troubles less. Serious trouble on feeders, when it does occur, however, obviously affects a much larger area than trouble in mains. The extent of area affected depends also on the arrangement of bus bars and class of apparatus in station or substation.

Substation Apparatus.—In substations supplying direct current, rotary converters with their accompanying step-down transformers and potential regulators, are used almost exclusively. The direct current ends of these rotary converters are often worked in multiple with an old generating station, at least during the peak hours of one or two months in the early winter. A storage battery with end cell switches for discharging on two or sometimes three different potentials is an important adjunct to a substation. The batteries in all substations are often discharged simultaneously at time of peak on principal generating station, or in an emergency; at all other times they are allowed to float on system. They are charged either by using a booster or direct from a rotary converter equipped with sufficient regulator and transformer capacity for working at the higher voltage necessary for charging.

Even in a substation having a storage battery and a subsidiary steam plant, all of the annual k.w.h. output, except a few per cent., is supplied to distribution system through the rotary converter. Special precautions are necessary to guard against interruption of service, as the radius of possible transmission of large powers in case of trouble is very much greater than in the case of services, mains or feeders.

The characteristics of a rotary converter are such that it will carry an enormous overload with very little drop in voltage. Serious troubles or short-circuits, whether they occur in the rotary converter and accessories, in the d.c. connections or in the a.c. connections, will be violent and are liable to be destructive unless the damaged unit can be quickly and effectually disconnected, both from the a.c. transmission and the d.c. distribution systems. The localizing of trouble and the effectiveness of disconnecting depends on the arrangement of the a.c. bus bars and the automatic safety devices.

The practice of operating practically all units on a single set of bus bars, at least during long-hour light-load period in the direct

current generating stations, undoubtedly had some influence on the earlier substation bus bar arrangements. In many large substations all rotaries are operated from one set of bus bars; in others they can be operated on either one of two sets of bus bars. Another arrangement consists in running all rotaries from a single bus bar arranged with disconnective knife switches, so that each rotary or group of rotaries could be operated independently from its own transmission lines. An improvement consists in replacing the disconnective knife switches with remotely controlled oil switches.

With the latter arrangement, each rotary or group of rotaries can be operated all in multiple if necessary or advisable, and be quickly sectionalized in case of trouble on any one transmission or conversion unit. An example is shown in Fig. 1, which gives the scheme of principal connections in a substation that was put into service about one year ago. There are twelve 500 k.w. rotary converters arranged in three groups of four, each group supplied from its own high tension line and delivering current to its own section of the direct current bus bars. The incoming lines, apparatus, cable connections and switchboards, and the low tension feeders to street, are all located and arranged to prevent a bad burnout spreading from one group to another.

On each rotary converter there is mounted a direct current circuit-breaker operated only by means of a 125 volt trip-coil. A centrifugal speed limit device on shaft closes the trip-coil circuit, thus disconnecting the rotary converter from d.c. bus bars, and preventing its running away, the causes of which are well known. A reverse current device also trips this circuit-breaker in any case of trouble that would draw more than a predetermined amount of energy from the d.c. bus bars.

The oil-switches on each individual rotary converter outfit, and those used for tie-switches, are all equipped with overload attachments, which are so adjusted that they will open only in case of serious trouble. The tie-switches should also be equipped with interlocking devices, so that these tie-switches between lines can be closed only when the two sources of e.m.f. are in synchronism. The low tension feeders in most of the large Edison systems are provided with very heavy fuses and often with solid links. The adjustment of overload attachments on oil-switches must, therefore, also be made for heavy loads and with due consideration for the particular conditions involved in each individual case.

Transmission Systems.—In most of the larger cities the 25

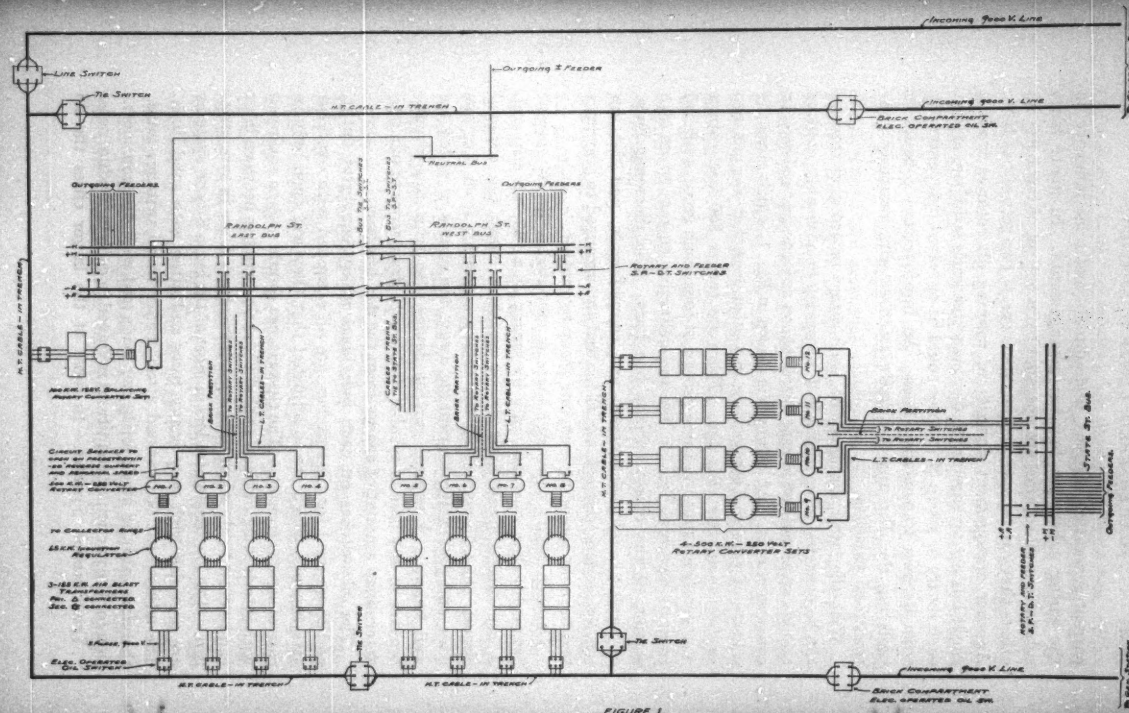


FIGURE 1

DIAGRAM OF PRINCIPAL CONNECTIONS IN A SUB STATION

cycle transmission systems are operated at voltages varying from 6,600 to 13,000 volts. Much higher voltages have been successfully used on through trunk lines, in several other cities. This, however, is obviously a very different condition. The large transmission systems with their multiplicity of lines, cable terminals and oil-switch connections have grown into networks that are continually becoming more complex. As each and every case of serious trouble anywhere on a system having almost exclusively synchronous apparatus necessarily affects every part of the system, the possible chances for trouble affecting any one of the thousands of customers, are also continually increasing. Commercially, this is a very serious matter indeed, especially when we consider that with many of the more desirable customers the greatest possible security for continuous service is of first importance.

Realizing this fact, many central station engineers have taken extraordinary pains with high tension cable work and in some cases have succeeded in making the transmission network in itself one of the most reliable parts of the central station system, except in so far that inherently this high tension network with its synchronous apparatus is lacking in elasticity.

This has been the experience in Chicago, where a 2,250 volt, 25 cycle transmission line supplying rotary converters, was first put into service about six years ago. Since then the transmission voltage has twice been doubled. The first line, three and one-half miles long, supplied one substation having 200 k.w. capacity in rotary converters. The resulting high tension system, shown in Fig. 2, will, by next fall, aggregate about 60 miles, supplying nineteen substations with approximately 24,000 k.w. installed in rotary converters and 4,000 k.w. in frequency-changing motor-generator sets.

About twelve months ago the potential was raised to 9,000 volts. The previous and subsequent experience indicated many desirable improvements. Until this time the system was supplied only through delta-connected step-up transformers from double current generators.

The capacity effect of lines was found to be such that in event of slight ground on one phase, it might result in an excessive rise of potential and very severe strain, if not an actual breakdown, on some part of system. The grounding of neutral on this high tension system has been attended thus far with very satisfactory results. As star-wound 9,000 volt alternators were

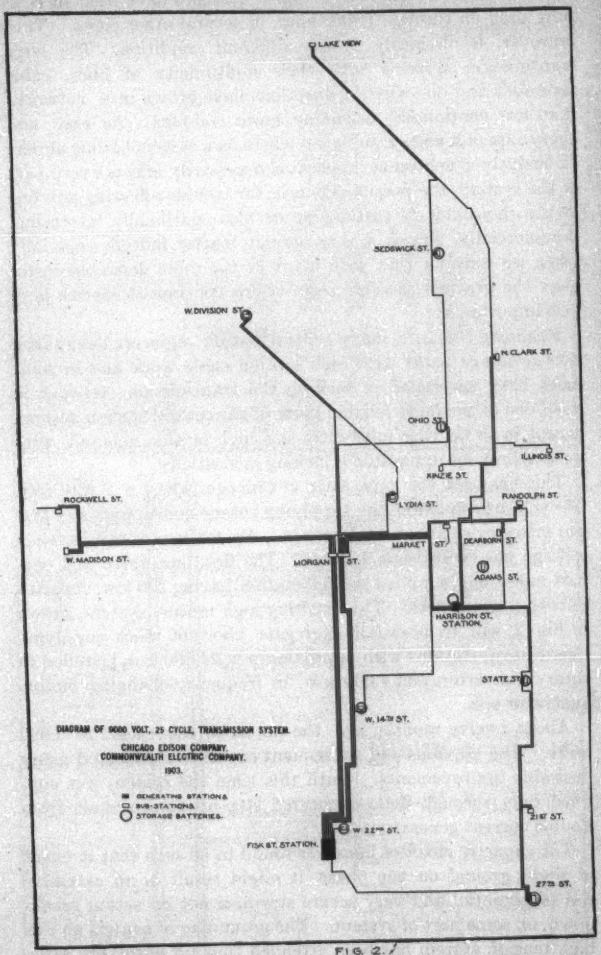

LAKE VIEW
SEDGWICK ST.
W. DIVISION ST.
N. CLARK ST.
OHIO ST.
ILLINOIS ST.
KINZIE ST.
ROCKWELL ST.
LYDIA ST.
RANDOLPH ST.
MARKET ST.
DEARBORN ST.
W. MADISON ST.
MORGAN ST.
ADAMS ST.
HARRISON ST. STATION.
STATE ST.
W. 14TH ST.
DIAGRAM OF 9000 VOLT, 25 CYCLE, TRANSMISSION SYSTEM.
CHICAGO EDISON COMPANY.
COMMONWEALTH ELECTRIC COMPANY.
1903.
GENERATING STATIONS.
SUB-STATIONS.
STORAGE BATTERIES.
W. 25TH ST.
21ST ST.
FISK ST. STATION.
27TH ST.

FIG. 2.

installed, the common point of winding was in each case connected to ground. Practically all high tension transmission cable installed during the past two years consists of No. 4/00 three-conductor paper and lead covered cable. The thickness of paper wall on each conductor is 6/32 inch, over all is 4/32 inch and lead wall is $\frac{1}{8}$ inch.

The arrangement and installation of terminal appliances is obviously of great importance. All forms of fuses and air-break witches have been abandoned, so that at present the main circuits are made and broken only under oil. Various forms and methods of making up joints and cable-heads were tried. These are now made up in parts, so that the lead sleeve or cylindrical part of head is put in place after the individual joints have been made and insulated with paper tape. The sleeve or cable head is then filled with a special compound, which is a non-absorbent of moisture and has a much higher dielectric strength than the paraffin which was formerly used. The process of filling is such that every minute particle of moisture is expelled.

The selection of routes for transmission cable is made with a view to provide two or more lines on different streets if possible at least in different groups of conduit for each substation. The cables are isolated and mechanically protected, so that the spreading of a bad " burnout " in either high or low tension cables will be prevented as much as possible. A well-designed and constructed conduit and manhole system is therefore essential. Overhead connections to an extensive high tension underground network are a source of trouble to be avoided, if possible. When unavoidable, these overhead taps should be isolated by means of transformers.

Generator, Prime Mover and Auxiliaries.—The necessity for operating all units in multiple for long hour periods in order to obtain good station economy, still exists to a very large degree. During the past ten years the sizes of units in the largest stations have been increased from 800 and 1,500 k.w. to 3.500 and 5,000 k.w. The number of units, however, in any one station has often been decreased, making multiple operation of at least a large portion of plant more necessary than before, and also placing much greater dependence on any one unit. Such stations have been and are still passing through a critical transition period. Every case of serious trouble on generator, engine or auxiliaries affects the entire system; but it frequently happens that the system cannot be sectionalized even into two parts without

serious sacrifice in engine economy. The gradual increase in number of units will only partially relieve this situation.

The engine-driven unit is ordinarily one of the most uncertain elements in the central station system. Duplicate units are often installed and operated side by side under apparently the same conditions, and one, for a time at least, will prove much more reliable than the other. There is so much fitting, so many fine adjustments and valve settings, all of which must be done with great care, precision and patience. Much depends also on the faithfulness and the skill of the men in immediate charge of the apparatus. This is true of any similar apparatus, but particularly of the large engine-driven units operating in multiple on transmission systems.

With an arrangement of bus-bars, high tension lines and substation apparatus similar to that shown in Fig. 3, generating units can be operated independently, and a certain amount of shifting of load can be done at the larger substations having four or more units in service. Rotaries can be shut down one at a time, transferred to another generating unit or another station and again put on load. During peak hours there would be shifting which would introduce some additional chances of trouble due to possible mistakes of men handling apparatus, which, in that case, would partly offset some of the advantages of sectionalizing.

In this respect, a very decided advance would be the use of a prime mover giving practically a straight line economy, such as the steam turbine. The differences between one-half load and full load performance for short hour periods will not be great enough to warrant much shifting. The auxiliary apparatus, particularly the condensing plant, is frequently a cause of trouble. The "sticking" of pumps, "dropping" of vacuum, and similar reports, are heard occasionally in every steam plant. The arrangement should be such that the condensing plant and auxiliary apparatus and the excitation of any one unit are simple and positive in operation and normally independent of every other unit.

Steam Supply.—Practically every steam plant has its own peculiarities in piping and arrangement of boilers, but in most cases all boilers are in one room. The bursting of a steam pipe or boiler tube fills the entire room with steam instantly, making it impossible to close a valve in the ordinary way. The location of boilers in two or three different rooms or floors and the providing

of means for closing valves from inside of engine room has lessened the danger of a shut-down. The placing in separate rooms, as far as circumstances will permit, of the boilers and piping corresponding to each generating unit and connecting only

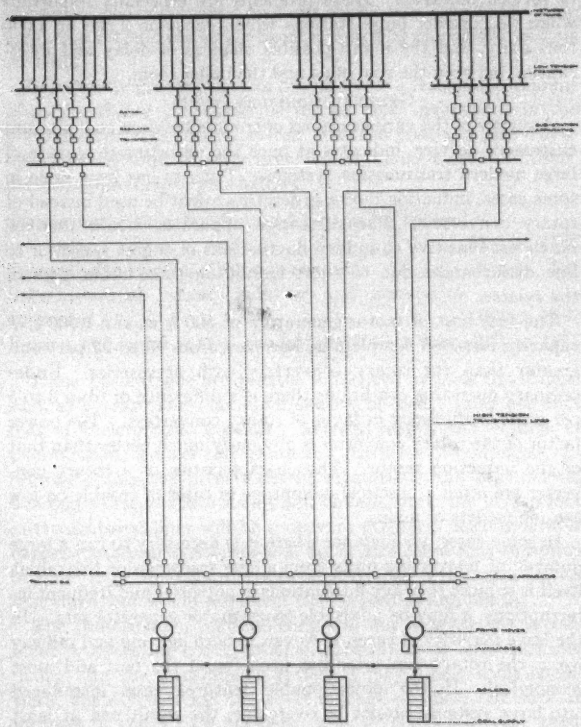


FIGURE 3.

DIAGRAM OF CONNECTIONS FOR STATIONS SUB-STATIONS AND TRANSMISSION SYSTEM ARRANGED FOR INDEPENDENT OR MULTIPLE OPERATION OF UNITS.

through fairly quick-acting remotely controlled valves will further lessen this danger.

With careful operation, customers' troubles (bad or interrupted service) that are chargeable to the boiler room are few, while those of the central station manager are many. Investiga-

tions, experiments and some improvements have been made from year to year, but the buying and economical handling of coal and making of steam still involve problems that are worthy of the very best attention, both as to the cost of operation and reliability of service rendered. These problems are especially important when we consider large stations which consume 2,500 or 3,000 tons daily, and the many possible chances of delay and interruption between the coal mine and the boiler room.

General Considerations.

A survey of the various classes of trouble between coal pile and customers' service indicates at once the unfortunate feature of large modern transmission systems. True, as has been done in some cases, induction motor-generators might be used instead of rotary converters. The substation apparatus would then be much less sensitive to sudden fluctuations in engine speed, or to line disturbances due to short circuit on some other part of the system.

The first cost of motor-generators of 500 k.w. and 1,000 k.w. capacity installed complete is, however, from 15 to 25 per cent. greater than for rotary converters with accessories. Under ordinary operating conditions there is a difference of from 3 to 5 per cent. in efficiency in favor of rotary converters. The power factor of the rotary converter is obviously much better than that of the induction motor. The characteristics of a rotary converter are often a practical advantage in cases of trouble on low tension feeders or mains.

In some cases, for instance where it is necessary to run a large number of converting units from a long transmission line which itself is subject to heavy fluctuations in potential and frequent interruptions, it may be advisable to use motor-generator sets. In the large majority of cases, however, in both lighting and railway work, the rotary converter has been found the best and most economical. If the objectionable features thus introduced into large systems cannot be overcome, the result can at least be minimized by judicious sectionalizing.

The electrostatic capacity of these large high tension cable systems is such that there is necessarily a practical limit to the mileage of cable that can safely be operated as an interconnected network. In the 60 miles of 9,000 volt three-phase 25 cycle lines previously mentioned the charging current as calculated will be about 16 amperes. At the present rate of increase in mileage the condenser effects will soon be troublesome and possibly pro-

hibitive, as troubles may occur which will result in building up a potential at some point and breaking down insulation on apparatus that was comparatively safe on the smaller system. In that event, and with several very large units all in multiple, the amount of power delivered on short circuit would probably be so great that it could not safely be interrupted by any oil-switch thus far built.

In a rapidly growing system provision for a reasonable amount of sectionalizing can easily be made. The investment in the portion of central station system between coal pile and customers' service most directly involved, is, under most conditions, divided approximately as follows:

Station-real estate, building and generating apparatus	35% to 45%
Transmission system-cables and conduit	3% to 6%
Substation-real estate, building and converting apparatus	10% to 15%
Feeders and mains-cables, conduit and Edison tube	40% to 48%

These percentages are greatly influenced by local conditions, such as average and maximum density of load; value per duct foot of underground conduit; average length and voltage of transmission; cost of real estate and character of buildings. In railway plants, the investment in substations and that corresponding to feeders and mains will be less, while the investment in transmission lines will be somewhat greater. A considerable capacity in storage batteries will, under load conditions obtaining in most large systems, decrease slightly the investment in the first three, but would not affect that in feeders and mains.

The provision for sectionalizing will not increase the investment or operating costs, either in substations or in feeders and mains. In the transmission system it may, under some conditions, slightly increase the total mileage of lines; but such an increase in the 3 to 6 per cent. thus involved is a very small increase in the total investment in entire system.

A review of power houses indicates that there is a wide difference in cost of station buildings. This difference is a matter partly of engineering and partly of management. Taking the total cubical contents of six of the large modern station buildings, we find that from 6 to 10 per cent. is devoted to coal storage and that the complete buildings vary from 100 to 240 cubic feet, and from .95 to 2.5 square feet per k.w. rated generating capacity.

The boiler room portion of the same stations vary in total net cubical contents from 65 to 130 cubic feet per rated boiler horse-power, while the engine room portions vary from 40 to 90 cubic feet per rated engine horse-power. As practically the same types of boilers are used, the former depends almost entirely upon the design and arrangement; but the latter depends largely upon the type of generating unit adopted. In the case of vertical turbine-driven units, the figure for this portion of plant can be reduced by at least one-half.

The tendency, however, in power house design is toward a much more liberal allowance for space for all equipment. The high voltage generators of large capacity and multiplicity of lines demand extraordinary switching apparatus which requires considerable space. A suitable arrangement and reasonable isolation of switching apparatus and connections need not require any additional space and should preferably be much simpler than that in many existing stations.

It would seem, therefore, that in the large modern power house sectionalizing and even entirely independent operation of units can be provided for with very little, if any, additional investment in the generating station or in any other part of the system.

While the independent operation of generating units would tend to minimize the effect on cutsomers of many central station troubles and thus increase the coefficient of reliability, there will also be some disadvantages. A heavy overload or perhaps short circuit coming entirely on one unit or group of lines might trip the oil circuit-breaking switches on lines, and the sudden release from load severely strain the prime mover. This cause would be improbable if, as indicated in Fig. 3, each generating unit supplies at least two different substations and when only part of the load would be thus released on any one generating unit.

If a short circuit occurs on a feeder supplied by a small group of rotaries, the percentage of overload is larger and after one rotary trips, the others will quickly follow. This might not have occurred with a larger group, when the percentage of overload would have been correspondingly less. All transmission lines should be equipped so that oil circuit-breakers at both ends of line open automatically in case of trouble, whether the entire system is operated in multiple or independently.

In the latter event, if time limit attachments are used with overload devices at the station, the amount of energy delivered at the point of breakdown might not only slow down the engine

but draw enough energy from network to trip the circuit breakers on all rotaries supplied from the particular generating unit. If operated as shown in Fig. 3, this would mean, under full conditions, an overload of 50 per cent. on the remaining rotaries in each substation supplied from three different generating units; 100 per cent. overload on those supplied from two, and a total shut-down of such small substations as are supplied exclusively from the particular unit in trouble. Usual result: low pressure on part of direct current system; no trouble elsewhere.

In event of multiple operation of the entire system, with several units in service, a large amount of energy from the station bus bars would be delivered until time limit overload devices at the station and reverse current devices at the substation cut out the troublesome line. Usual result: heavy fluctuations in pressure on entire system, until line is opened at both ends, several machines shut down and sometimes a total shut-down of transmission system.

During the hours of light load the transmission system would naturally be divided into fewer parts or perhaps all in multiple. In event of a shut-down during these hours, the capacity of storage batteries would be so much greater in proportion to load that the drop in pressure would not be so serious.

The successful operation of large systems necessitates the maintaining of a well-organized operating force of competent and experienced men. Every operation involving the starting or shutting down of a generator, line or substation unit should be carefully regulated and checked to reduce to a minimum the possibility of a mistake. In one of the large stations now under construction provision is made for a LOAD DESPATCHER, whose office will be convenient to the operating switchboard and who can control absolutely the transferring of load between all generating, transmitting and converting units, with the same implicit confidence and accuracy of judgment and action as can the train despatcher on an important railroad system. His office should be a clearing house for all orders concerning operation of system.

After considering some of the advantages and disadvantages of multiple and independent operation in large underground transmission systems, it might be of interest to consider small overhead systems. The latter are operated independently, in very many cases with satisfactory results as to reliability of service rendered. In order to secure more economical engine per-

formance, it was necessary to adopt large units operating in multiple. This step also improved the reliability of service rendered, particularly where each feeder emanating from the bus bars continued to supply its own independent system. If these small systems of taps radiating from a center of distribution at feeder ends, had been arranged into one interconnected overhead network covering a large area, the coefficient of reliability with the same character of construction would undoubtedly have been decreased. These systems, usually supplying current for induction motors and for lighting, are fairly elastic; but on account of the higher potential usually, 2000 volts or more, a short circuit obviously affects a very large area and often the entire system. The matter of regulation being comparatively easy, there is, therefore, a distinct advantage in operating independently the different feeders instead of on an interconnected network. With an overhead system exposed to the elements and so many chances of interference from an exterior source, a modern station is usually the more reliable part of such a system, and therefore there is little necessity of sectionalizing the station. As a precautionary measure, however, and to facilitate future extensions and repairs, stations should be designed so that this can be done.

In conclusion, it might be said that considering responsibility for the business and return on investment, every central station system should be designed, if not for independent, at least for sectional operation. In the very large stations, the independent units from coal pile to distributing network, or to rails, should be effectively isolated to make a total shut-down practically impossible. The matter of independent, sectional or multiple operation at different hours of the day or days of the year is entirely one of local conditions, which may change frequently. Great care and constant attention is needed to maintain a fairly uniform and consistent coefficient of reliability on every part of the central station system. Independent and even sectional operation will mean a small sacrifice in operating costs. With a system properly designed, this matter, then, becomes to the central station management a plain business consideration; to take the risk of inferior service and possible shut down, or to pay a premium in the form of very slight sacrifice in operating costs and thus obtain an additional safeguard for superior service to all or such groups of customers as business requirements may demand.

DISCUSSION.

We take up to-night a number of papers dealing specifically with different combinations in the system of distribution, and the first paper will be that on "Economical and Safe Limits in the Size of Central Stations," by Mr. H. A. Lardner, of New York City.

Mr. Lardner read the paper. (See page 635.)

PRESIDENT SCOTT:—The next paper is on "Safety Devices in Central Stations and Substations," by Mr. Philip Torchio, engineer of the New York Edison Company.

Mr. Torchio read the paper. (See page 645.)

PRESIDENT SCOTT:—We are fortunate this evening to have among those who are to present papers, two gentlemen connected with large and important companies. We have just heard from the engineer of one of the larger companies in New York, the large lighting company, and the company which provides power for general distribution. We also have with us a gentleman from Chicago, one of the other large cities of the country, who represents one of the most notable plants of the country. Mr. Peter Junkersfeld, engineer of the Chicago Edison Company, will now present his paper on "Multiple versus Independent Operation of Units and Central Stations."

Mr. Junkersfeld read the paper. (See page 653.)

PRESIDENT SCOTT:—The papers which we have had this evening are of exceptional value on account of their particular character. In dealing with the subject of central station practice, they have not gone into generalities, they have not dealt with matters in a theoretical way, but we have had in the last two papers, in particular, what we might call heart-to-heart talks from the men who have been operating large stations for a considerable time. The burden of the papers, particularly of the last two is notable—it is not the general theory of the interrelation of parts, not on the characteristics of engines or dynamos, of efficiency or regulation, nor do the papers refer to those elements which come up in connection with the design of the station beforehand, but they have more to do with the operation of the station, with the things which affect the man who runs the station They have to do more particularly with the emergency conditions, with safety devices; and through all the papers we have this sentiment—how shall we protect the station against emergencies and interruption of service? We might be led to think that these papers are chapters from experience, and one might almost conclude that Mr. Torchio has given us the results of thirty-three accidents and shut-downs in his system, but we fortunately have already been assured that this is not entirely the case, by Mr. Lieb's statement incorporated in my introductory remarks—that this same system has been running since its beginning, always with some current on its lines, and for some ten years with no interruption of the service.

We are in debt this evening especially to one of the mem-

bers of the Committee on Papers, who has had this meeting in special charge. He is the superintendent of motive power of what was the Manhattan Railway Company, and is now a part of the Interborough Rapid Transit Company, of this city. He has given me a list of some gentlemen whom he suggests I call on for discussion this evening, and I will reverse the order in which he has placed the names, and begin with the signature at the bottom and call upon Mr. Henry G. Stott.

MR. STOTT:—It seems to me that to-night is a good time for us to look back. We have been told a good deal about modern tendencies. History seems to repeat itself. We started out fifteen years ago with one machine and one circuit all the way through; a little later it became a question of adopting two or three circuits, and having them so divided as to suit the size of the units. A little later the size of the units was increased, and also the size of the feeders which they supplied. Then it became a problem of combinations, how to adapt the feeders to the size of the machines. At that time everything was run, practically, with high-speed engines and high-speed belted generators. Following that came the period of slow-speed engines, and we began to look then into the possibilities of multiple operation. Multiple operation meant, instead of running five, six or eight small units on perhaps 50 per cent. load for the greater part of the time, for the service to be combined on one or more machines, thus producing a fair load factor. Then as soon as multiple operation came, with low speed engines, we began to look around for some further development; and there seems to be at the present time a tendency to go back to the higher speed generator, such as with the steam turbine. The steam turbine is practically an unknown quantity to most of us, and while some results have been published, yet it has not been in use long enough to justify a prediction that it will displace reciprocating engines. Reciprocating engines to-day are built with higher steam economy than is claimed for the turbine. I understand that tests with the Sulzer engine in the Moabite station show a consumption of 8.97 lbs., of steam per indicated horse-power. The larger units in operation in New York to-day are all approximately consuming about 13 lbs. of steam per indicated horse-power. That corresponds approximately to 19 lbs. per kilowatt hour. The best of actual records of the steam turbine is just about that. By going into triple expansion engines, a step which seems obvious for railway power or lighting plants, we can get down 20 per cent. lower than that, without any trouble at all. I had a message from the Boston Edison Company to-day, in which they advised me that with a 1200 h.p. compound condensing engine, with 98° of superheat at the throttle, they got a steam consumption of 11.57 lbs. per indicated horse power. At the present time I feel personally, in regard to the steam turbine, that we will have to return the Scotch verdict of " Not Proven," and wait until we get actual results.

The feature of the floor plan, the space in relation to the general size of the plant and the unit, has been referred to. I think a little consideration will show that the size of the generator unit has nothing to do with it. It is the size of the boiler room. If we can reduce the size of the boilers, we can reduce the size of the station, but to get an economical distribution of steam from any plant, we must run the boiler room parallel to the engine room. I believe you will find that the limiting feature in all large stations, no matter what the size of the generator unit, you must have a certain size of boiler unit; and to get the best distribution of steam, even though the units only occupied one-fourth of the space claimed for the steam turbine, you would have to space the steam turbine units at approximately the same centering distance as you do the steam engine, so that the economy of floor space I do not think is a very important point.

Coming to the transmission lines, the claim has been made, and I think it dwells in the minds of many able engineers, that the high-tension lines are very dangerous. I differ from that. I think the high tension underground cable is the safest thing we have—a great deal safer than low tension. If you have a short circuit in a low tension cable, it may burn up a thousand feet of the cable before you can stop it. If there is a short circuit on a high tension cable, with proper safety appliances on each end of it, it does not destroy more than two feet of it. We have quite a large capacity on the bus bars in the Manhattan plant—over 45,000 k.w., all in multiple—and we have had short circuits on the high tension feeders of 11,000 volts, and the result is a puncture such as you would get from a testing transformer, not destroying more than two feet of the cable, whereas with a short circuit on a 600-volt direct-current cable, a large amount of cable may be readily destroyed.

I think the storage battery has found its proper place as an assurance against shut-down and not as a means of economical operation. That statement is probably open to discussion. It seems to be almost impossible to find a condition in which the storage battery pays for itself as an investment. I believe it is used essentially as an insurance, and not as an element in economical operation.

The idea which pervades all of these papers, namely; the returning to the single operation of units on a certain number of feeders, or employing a certain number of sub-stations, without multiple operation, seems to be a backward step. It is a confession of weakness in our safety devices. Is it not a better solution to improve the safety devices and operate in multiple and thereby gain the maixmum economy of station operation? The price of coal is soaring all the time and apparently always will do so, and in the operation of a plant coal forms over 60 per cent. of the actual cost of power; and it is therefore most important for us to do everything possible to economize. This can only be done by running the units as near full load as possible, and to

do this we must run in multiple. The separation of high tension apparatus can be very easily carried out, and it seems to me that by means of proper appliances as indicated in Mr. Torchio's paper, and as actually carried out, there is no difficulty whatever in making a station practically safe in all kinds of operation. I have seen an actual short circuit in a station with four 5,000 kilowatt machines in multiple, and an oil switch, take care of it perfectly, long before the attendant could touch the switch and throw it out. With a switching apparatus brought down to such perfection as this, it seems to me that we ought to be very careful about reducing the efficiency of operation of our plants by going into independent units or plants. I believe this covers all the points I had in mind to present this evening.

THE PRESIDENT:—We have with us this evening a gentleman who has been connected with central station work for some ten or fifteen years, Mr. Herbert A. Wagner

MR. WAGNER:—I can add very little to the remarks which have been made to-night in the papers that have been read. I have recently been connected with the engineering work of the Boston Edison Company, and there we have so far operated all the alternating current generators and feeders in multiple. We have had practically no trouble. The generating station, until three years ago, was used for alternating current distribution only. It is now used entirely for transmitting current to substations from which current is distributed on the three-wire direct current system. All these substations are equipped with motor-generators in place of rotary transformers, and I attribute the freedom from many of the troubles which other central stations had to the use of motor-generators in place of rotaries. A large proportion of the motor-generators are induction motor-generators, and therefore the troubles which are often caused by a great amount of synchronous apparatus, are obviated. Of course, there is something to be said against the use of motor-generators. The first cost is something more; the power factor with induction motor-generators is lower, but with a proper apportioning between induction motor-generators and synchronous motor-generators that can be improved.

The company is now building a 50,000 k.w. station, in which turbines in 5,000 k.w. units are to be used entirely in place of engines. This station will probably be operated in sections, but that has not yet been definitely determined. I would like to correct the statement which Mr. Stott made; since he evidently is misinformed. The engine economy which he quoted in reference to the Boston Company, refers to the cross compound engine and not triple expansion. I think the German practice and experience has shown that there is nothing to be gained by the use of triple expansion over compound engines, especially without superheating. They have carried superheating to a very much higher degree there than here, as they have used independent superheaters. In this country nothing over 100°, I think, has

been reached, and that is much above the average practice, which is 75° to 80°. With a high degree of superheating, I think the cross compound can be made fully as economical as the triple expansion engine. Single cylinder engines, with high degree of superheat, have almost equalled compound triple expansion engines, but the difficulty of using such high degrees of superheat is almost insurmountable, especially with the type of engines used in this country.

PRESIDENT SCOTT:—Is Mr. F. A. Waldron, here? If so, we would like him to participate in the discussion

MR. F. A. WALDRON:—As I have prepared a paper, covering detail tests, to be presented at the June meeting of the American Society of Mechanical Engineers, I hardly think it would be just to the Society to which I belong, or to myself, to anticipate this paper in any of the remarks which I might make this evening. Therefore, I will make a few general remarks, in which all quantities will be stated in round figures, subject to such modifications as more detail may develop.

After listening to the opinions and remarks on the steam turbine, this evening, by different members, I find that my own feelings in relation to the turbine, two years ago, were the same as theirs are to-night, although, when I drew the following parallelism, I did not realize that so unanimous sentiment existed.

As a disciple of E. D. Leavitt, of reciprocating engine fame, my experience with the turbine has been very much like the experience of the Provençal, in Balazc's " Passion in a Jungle," when he discovered the blood-stained panther in the cave.

1st.—A fear and a desire to get as far away from it as possible.

2d.—A natural curiosity to see how the " animal " would act (with a very grave doubt in my mind that it would act as I wanted it to.)

3d.—Its graceful outline; the space occupied; the alluring " blue book " by Mr. Hodgkinson, on how little water it consumed—gradually overcame my natural temerity and I became more curious.

4th.—I approached the " animal " with the determination of finding out how it would act, when awake, feeling all the time that it would be well to keep a knife (hammers and monkey-wrenches) at its throat.

5th.—To make a long story short, I have become acquainted with and learned to admire the " animal," and although I have never laid down to sleep with it, I wanted to very badly, last August, when a wire in the field broke, and I did not sleep for 48 hours, while it was being repaired.

Personally, I regard the turbine in relatively the same light as the sewing-machine, and I do not think, for one minute, that the reciprocating engine builder need take the same stand that the spinster did, at the time the sewing-machine was invented, and petition Congress that it be suppressed. It has its special field and is not, in any way, a universal power panacea or a patent medicine remedy for power ailments.

On the other hand, it is a remarkable stride toward the goal of economizing power distribution, and the claims made for it by the builders have been substantiated in every way. I have found the following points in the machine that appeal most strongly to the business man and to the engineer in charge of the operation of plants, at the present day:

(*a*) Simplicity.
(*b*) Ease of operation.
(*c*) Economy.
(*d*) Lack of multiplicity of moving parts.
(*e*) Continuous or commercial efficiency.
(*f*) Floor space.
(*g*) Cost.
(*h*) Cost of buildings.

I have not named these in their order of importance, as one is almost as important as the other; and will take up, briefly, a discussion of the points in the order above named:

(*a*) SIMPLICITY.

After the machine is properly placed, balanced and started, there seems to be (outside of defective materials), nothing in it which can give any trouble.

(*b*) EASE OF OPERATION.

Two lubricators which require filling twice each day; an occasional trying of the oil, cooling-water cocks and the small air cocks on top of the bearings, together with an occasional lubrication of the collector rings, is all that the running engineer has to look out for, in as far as the turbine and its generator goes.

(*c*) ECONOMY.

The Yale & Towne outfit consists of a Westinghouse-Parsons turbine and a 400 k.w., 2-phase, 240-volt, 7200 alt. generator, driving induction motors from ½ to 40 h.p.

This is the first plant to be operated for regular factory driving, outside of that the Westinghouse Company, having been in service since February 1, 1902.

To be sure, this is a small plant, as compared with those mentioned this evening, but it is the small plant that worries, as to whether it is better to put money into betterments or the coal-pile, since in such the line of such demarkation is very fine.

A breakdown, due to defective forgings, occurred last January, on a new field which had never had a load upon it. This has in no way destroyed our confidence in the machine, and a second unit has been ordered.

With a 400 k.w. load, running at about 150 lbs. pressure, per gauge, at the throttle, with from 10° to 15° superheat and about 27½ inches of vacuum, an economy of approximately 22½ lbs. of water per k.w. per hour at the switchboard, has been obtained. This economy is the result of tests from daily running loads and is in no way a special test; the discharge from the surface condenser determined the amount of water used, and the condenser was tested for leakage before the tests were made.

(*d*) Lack of Multiplicity of Moving Parts.

This is very noticeable and impressive to one who sees the turbine for the first time, and I shall never forget my disappointment in finding it so simple a machine. The governor and an oil-pump are about all that *seem to be going*, when the machine is running.

(*e*) Continuous or Commercial Efficiency.

By this I mean that it is inherent in the design of the machine to run continuously and at varying loads within certain limits, at its maximum economy, owing to the fact that there are no cross-head slides to get out of alignment; no piston packing to wear and replace; no stuffiing boxes to repack; no valves to reseat or grind up, and no bearings to key up—all of which tend to reduce the daily running efficiency of any reciprocating engine plant.

The effect of changing engineers in a moderate-sized plant, and its effect on the coal-pile, are unknown quantities in so far as reciprocating engines go. We all know however that when the new engineer comes on everything has to be readjusted; and where there is one that knows how to make proper adjustments, there are a dozen who don't, and as a general proposition it is safe to say that the average sized plant, in the course of ten years, gets more engineers that don't know how to make proper adjustments than those who do. This is one of the chances of war which the reciprocating engine owner has to take and as a natural consequence must pay for.

The personal equation of the engineer, and its effect on the coal-pile, is entirely eliminated in the steam turbine.

(*f*) Floor Space Occupied.

It is possible to place about three times the power, in turbo-generator outfits, in the same space occupied by a direct connected horizontal or vertical engine of approximately the same economy.

(*g*) Cost.

The cost of the turbine, with its accessories, ready to run, is from 10 to 15 per cent. less than the reciprocating engine of the same power, provided high-grade makes *only* are considered. You can buy a reciprocating engine equipment cheaper than you can a turbine; but personally I do not think that such are to be classed in truly competitive prices.

Weight, complete, 33,000 lbs.

Weight, reciprocating engine same power, with generator, 200,000 lbs.

(*h*) Cost of Buildings.

The cost of buildings in our particular case per k.w., would be about 65 per cent. of the cost of buildings housing the same amount of power with the reciprocating engine.

There are one or two points in the turbine, especially in the installation of the machine, which should be carefully watched.

1st.—To place the turbine, with relation to condenser, so that there shall be plenty of chance for expansion and contraction of the machine itself.

2d.—In piping up for cooling water, it is well to have two sources of supply; also, an eel-trap and by-pass on the inlet to the oil-cooling coils and the try-cock to an open drip on the outlet of the coils.

The exciter outfit should never be driven by a motor or the turbine itself; an independent, direct-connected set is the only way to do the trick, unless you wish to take chances of shut-down, especially if you have inductive loads.

Oil should be changed and filtered every week.

The present construction of the turbine is such that it has one very weak point which the reciprocating engine has not, and I will mention it, briefly, before closing. The reciprocating engine, designed for a certain horse-power, may have its most economical point of cut-off from a .28 to .33 stroke in the high pressure cylinder. In the event of the vacuum being destroyed and the relief-valve to the atmosphere opening, the reciprocating engine naturally takes more steam and keeps the machinery up to speed, even though it has to carry about .7 or .8 stroke in the high pressure cylinder.

The turbine however will not do this when running from three-quarters to full load. It is necessary for the engineer to be on hand to open the by-pass and cut out the high pressure blades, in order to keep the machine up to speed. This can be done, if the engineer is always in the same place, but he isn't always there. The result is sometimes a shut-down through conditions which are entirely beyond the engineer's control.

I am informed that designs for avoiding this trouble are being perfected.

The electrical end of the machine is of course the one which you are probably most interested in and *that* end is really one which I am at a loss to describe, as the extent of my knowledge in the electrical line is always to keep one hand in my pocket when around any machine generating electricity. Since coming in actual contact with the installation and operation of a turbo-generator unit, the meaning of *power factor* has been drummed into my head by hard knocks. Should any member of the committee who established the power factor specifications ever want the position of running the Yale & Towne turbo-generator, under the conditions which we have been running in the past year, I think that after he had been on the job for about six days he would willingly admit that there are two sides to the power factor question.

I understand that a specification was established by a committee (appointed by the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS,) which states that the power factor for alternating current machinery specifications should be based between 90 and 100 per cent., at the normal output of the machine.

If I am not mistaken, at that time these specifications were based on the requirements of the times, and from the best practice and data then obtainable. The induction motor was then comparatively an untried machine. Almost everything in the electrical way was direct current, and the alternating current was taking its place in long-distance transmission and lighting requirements. At the present time, however, and the immediate future, the probable method of power transmission from central stations will be by the alternating current generator and the brushless (induction) motor. This being the case for the average sized plant, a power factor of from 80 to 85 per cent. will be nearer the average for work of this kind than 90 to 100 per cent. The query then is—Does a man actually get what he thinks he is getting, when he buys his machine? To the electrical engineer, familiar with alternating current, all of this is very plain, but I have met many electrical engineers who have always made a study of direct-current work, who have been somewhat "phased" in the matter of power factor. Let us assume, for argument, my own case. I place myself at the mercy of reputable builders, stating that I require a 400 k.w. machine. I receive a specification with the standard power factor of between 90 and 100 per cent. incorporated therein. I purchase the machine and start it up, with the idea of carrying the full k.w. rating of the machine. Upon applying the load, I find that the ammeters show between 25 and 33⅓ per cent. in excess of the carrying capacity of the generator terminals, with proper temperature limits. I also find that the current required to run my exciter is in excess of the requirements in the specification. I further find that the rise of temperature in my field, to carry the load, is more than it should be. Under these conditions, I begin to make inquiries and find that it is very seldom that a plant carrying a purely inductive load reaches a power factor of above 85 per cent. In most cases plants of moderate size, with variable loads, will seldom exceed 82 per cent.

A natural answer to this is, " Well, he ought to have known better." I will admit it; but yet there are hundreds of others I have found since that haven't any idea or conception of this bugbear, power factor. I hope you will pardon my aggressiveness in this matter, and not take it as an affront to the hospitality which you have extended me in suggesting that a standard specification and rating shall be made for alternating current generators, running under inductive loads, with power factors lower than those already specified; and in this way large manufacturers would have a specification which, if read by some mechanical engineer, would not mislead him into thinking that he was buying a " gold brick." Some standard form of this kind would undoubtedly be for the mutual advantage, both of the mechanical and the electrical engineer, especially with the tendency to the centralization of large power plants; and, as the induction motor with the turbo-generator is designed to become a potent

factor in the future development of this centralization, it would seem but fair and just that the issue should be looked squarely in the face and met, not only from the standpoint of the expert electrical engineer, but also of the purchaser.

It was only this afternoon that a mechanical engineer, in charge of some large mills in the east, called on me in regard to the question of centralizing a plant aggregating from three to four thousand horse-power, and using the alternating current with induction motors. He was looking at it through the same glasses that I did, when the machine was purchased, namely; that a 400 k.w. machine was good for 400 k.w., regardless of the character of load.

In conclusion, as a general proposition, the electrical engineer has very thoroughly and gracefully placed the turbo-generator proposition up to the metallurgist and mechanical engineer, and it is now fairly and fully up to them to solve the problems of a high speed, and the ability of materials to withstand such speeds under continuous running conditions.

PRESIDENT SCOTT:—On the list of names handed to me appears the name of Mr. E. H. Sniffin. We will be glad to have Mr. Sniffin take part in the discussion.

MR. SNIFFIN:—There is one point which occurred to me, particularly in connection with the steam turbine, and that is the question of economy. I think we are all tolerably familiar with what the reciprocating engine will do, and it is probably a fair statement to say that the steam turbine will not give materially better results, under full load test than the best known results of reciprocating engines. Under light loads, of course the turbine is more economical, but I wish some one were wise enough to tell us what reciprocating engines do in everyday service. I think as we accumulate experience we will find a distinct difference between the inherent, commercial, everyday efficiency of the turbine and the reciprocating engine. This has been already shown by the amount of experience we have had. For instance, at Mr. Waldron's plant he is getting results which will soon appear in his intended paper, and I think will bear out the remarkable commercial efficiency of his plant operated by the turbine. I might say, too, at Hartford, Conn., where there is a good-sized turbine running, 1500 k.w. machine, they have found by pretty careful experiments that they develop, as I recall it, about 1900 k.w. with the steam turbine, as against 900 k.w. for two Corliss engines, with the same fuel consumption. Possibly the engines were not in the very best condition; it may be the valves were not well set, or the internal condition of the engines not exactly as it should be. The turbine, of course, is direct connected, and the engines drive the generators by belting, and to the belt-drive we may ascribe some of the deficiencies of the steam engines, but certainly not all. We should not be misled in comparing the efficiency of two different types of apparatus simply by tests of them. The results obtained by

everyday use give the correct measure. As these new plants are installed and we get the actual results of the commercial operation, I think you will find in the commercial efficiency of the turbine a very marked improvement in general steam plant practice.

PRESIDENT SCOTT:—We would be pleased to have Mr. John W. Lieb, Jr. participate in this discussion.

MR. LIEB:—I will not take up much of your time, considering the lateness of the hour, but will make one or two observations on the papers which have been read. Reading over Mr. Junkersfeld's and Mr. Torchio's paper, one would be almost inclined to think that Mr. Lardner had a great advantage from the standpoint of safety of operation in a considerable number of smaller stations. I think, however, that Mr. Lardner in his statement of the case for a multiplicity of smaller stations, has probably not taken into consideration the extremely important factor in locating such smaller stations in such a city as New York. I certainly do not agree with his statement that it is not a difficult matter to locate smaller stations within the district of New York City; I mean in the Borough of Manhattan. I think any one who has undertaken to operate an electric light station on Manhattan Island will have become very soon convinced of the great difficulties which attend a selection, such as the bringing of coal to the station and the drawing away of ashes, and the liability of annoyance to the people living in the neighborhood. These things are all included in the difficulties of securing a proper location. As the state of the art progressed to a point where it was possible to concentrate the chief generating plant, so that these objectionable features would be minimized, it would soon become evident that such a step was necessary.

I would say also that if prospective customers of the electric light and power companies could read over this very formidable list of all kinds of automatic overload and underload relays, and other things tributary to the operation of a large power station, I am afraid the contracts which come in would be few and far between; as a matter of fact these requisites are rather in the direction of extreme refinement, necessary to secure the greatest regularity of service and the greatest freedom from disturbance.

I notice in these papers a question that is linked very closely with the problem of whether we shall have one large station or a number of small stations, and that is what one of the gentlemen has referred to as the commercial risk. It is perhaps true that if an accident should happen to a large station it may possibly involve a larger territory and therefore a large station perhaps might not be as absolutely safe as a number of small ones; yet that safety can by proper engineering methods and careful installation be increased to a point where the risk is entirely a commercial one. I think that has been fairly demonstrated in the operation of the large central stations which have supplied

the larger cities where the exigencies of the services are great; and I would emphasize the absolute necessity, as auxiliary of storage batteries in such systems of distribution. I think it is perfectly safe to say that the experience of all large central stations operating transmission systems to substations has shown that the storage battery seems an absolute necessity.

It seems to me Mr. Lardner has made a rather formidable list of advantages of large stations and has cited as the principal and only disadvantage the possibility of current interruption; but I am afraid that he has not, perhaps, sufficiently emphasized the very large difference between operating a dozen or more small plants and one large plant; and I wish particularly to emphasize in the case of a large number of smaller plants the volume of what may be called unproductive labor, the people you must keep at the smaller plant, no matter what its output may be. While the various matters which have been spoken of this evening might seem to indicate that the service from these larger plants may perhaps be less reliable than the service from a multiplicity of smaller plants, I think the experience that has been had in that direction already sufficiently demonstrates that the service which the large plants can produce is sufficiently constant and reliable for the most exigent and difficult conditions.

PRESIDENT SCOTT:—Mr. Lieb in his advice to central station designers uses the same sentiments that Mr. Carnegie employs in giving advice to young men—put all your eggs in one basket, and then watch that basket. The subject is open for general discussion and we would be glad to hear from any of the members who wish to speak upon it.

MR. TOWNSEND WOLCOTT, New York:—If I understand the theory of the steam turbine, there would not be the same advantage in the use of superheated steam in it as in the reciprocating engine. The superheating of steam in the ordinary engine is merely for the purpose of preventing condensation in the cylinder, for when saturated steam expands adiabatically while doing work, there is bound to be some condensation, owing to the conversion of heat into mechanical work, but, on the other hand, if the steam expand adiabatically without doing work, there is some superheating due to the expansion. If the work done upon the piston in expansion be accurately adjusted to the equivalent of this superheating, there would be neither superheating nor condensation; the steam would remain saturated. Now, in the De La Val turbine, and I think to some extent in the Parsons, the steam is expanded without doing work upon the buckets, the energy being finally imparted to the buckets by the impact of the swiftly moving mass of steam (or water). This steam, in the De La Val turbine, travels at the rate of about one thousand eight hundred feet per second, and to obtain the highest efficiency the periphery of the turbine should travel at one-half this speed, or about the velocity of a musket ball. This is out of the question mechanically, so at the highest practicable velocity there is a

considerable portion of the kinetic energy of the steam lost in the exhaust or tailings. It would seem to me that the only effect of superheating the steam for such a turbine would be to add to the energy thus rejected; particularly when there may already be some superheating due to the expansion.

MR. W. S. RUGG:—Mr. Lardner has brought up the point that we can expect nearly the same economy in a small station as in a large station. This, I think, is an important point and one with which we are all somewhat familiar, although Mr. Lieb has also shown that the cost of operating a number of plants is increased considerably over the cost of operating a single large plant.

Mr. Torchio has called our attention to the importance of isolating and duplicating the various parts of the distribution system. This is one of the directions in which most advancement has been made in central station practice during the last few years and one which is not as generally known and considered as it should be.

Mr. Junkersfeld called attention to the importance of isolating a boiler plant and dividing it into several units. This is a question I believe which has not been considered as fully as it should be.

All of these points are of great importance and it therefore surprises me somewhat that we have not heard suggested to-night a type of station in which all of the above advantages could be combined. We have yet to hear the first attempt so far as I know actually to lay out a multiple unit station, *i.e.*, a station made up of a number of unit stations each separated from the other by dividing walls but so arranged as to be operated together. In such a station I believe we could combine nearly all of the advantages which have been brought out in the papers, and it could be so designed that the operating expenses would probably be very little more, if any, than the operating expenses of a station occupying one room.

MR. ABBOTT:—The papers this evening are exceedingly important, particularly from an engineers' standpoint, but there may be another side to the question; namely, the standpoint of the general manager. Is it not possible to consider the question of the necessary safety appliances and the question of subdivision of the central station into a number of units as an economic problem, and to consider whether the greater cost of additional appliances for safety or of sub-dividing the given station capacity into a number of smaller units is warranted when compared with the risk of injury to service by omission of safety appliances or concentration of a larger plant in a single building. One of the papers this evening referred to the Niagara plant and mentioned that after the recent disastrous fire some of the engineers were reported to have stated that there should have been two bridges and two sets of cables. It is easy to shut the door after the horse has escaped, and to point out the desirability of duplication of plant after the accident has oc-

curred; but it is very certain that the Niagara engineers in the original design considered a single bridge and one set of cables amply sufficient to meet all contingencies.

Suppose the city of New York should be served for light and power from a single station, and all the machinery necessary for supplying the island be concentrated in a single station and a company should be formed to insure all customers against interruption of service in the same fashion that a fire insurance company assumes risk of loss from fire. Suppose upon the other hand that the necessary plant for serving Manhattan Island should be sub-divided into ten or more different stations. What would be the relative premiums for the two cases? The latter plant would be more expensive to construct and more expensive to operate, but if properly designed there would be almost no possibility of interruption to service, for if one station were incapacitated, the other nine would probably carry the extra duty without difficulty. With one station, even with the best design and most careful operation, occasional interruption to service, for greater or less periods of time would be likely to occur. The question is whether the extra investment in sub-dividing the plant and the extra cost of operation would represent a capitalization sufficient to pay an insurance company to underwrite all consumers in such a manner as to recompense them for any interruption. This is a business proposition.

Now, would it not be possible for some of us to contribute to the general knowledge on this subject in an endeavor to show perhaps graphically the relation between the number of interruptions to service in the territory served by one large plant as contrasted with the number of interruptions where service is given from several small plants.

MR. JUNKERSFELD:—The question seems to be one of multiplicity of small stations as against one large one. Mr. Lieb pointed out clearly that a multiplicity of plants is impracticable, because the companies must locate their power stations where coal and water can be easily obtained. This has been found true in Chicago also.

I fully agree with Mr. Stott and would rather have trouble on a high tension cable than on a low tension one, and in our experience in Chicago we have had very little trouble from breakdowns in high tension cables. In fact, during the last year, we have hardly known what it was as far as the high tension cable itself was concerned, except that when interconnected, disturbances were transmitted from one part of the system to another.

The question of the storage battery was brought up by Mr. Stott with the statement that as an investment he could not consider it economically. This is largely a question of conditions. In his situation it is possible he cannot see any great saving in installing storage batteries, but in the lighting business, with narrow peak, it is easy to see how a storage battery can be installed and used with profit up to a certain capacity. If you

cut off enough of the peak so that is it more than say an hour and a quarter wide, the battery will not pay. With a peak of one hour the battery will pay better than the equivalent capacity in generating apparatus.

Returning to multiple and independent operation, it has been shown this evening that a multiplicity of plants have some safeguard over one large plant. During the past two years the work in Chicago has been carried on with the idea of sectionalizing the substations and the transmission system. As the generating units were quite large, very little sectional operation was possible on account of the great sacrifice in steam economy with reciprocating engines. With the installation of the turbine units, having a good one-half load economy, sectionalized operation will be entirely possible. I was glad to know that here in New York, they had actually started operating their large plant in two sections, even with reciprocating engines, and I think the fact that they have found this advisable will be given a good deal of consideration in other stations, because what is done in the large lighting stations, is usually based on thorough investigation and wide experience, and is a matter of interest to all stations.

MR. LARDNER:—No one knows better than Mr. Lieb the difficulties of operating many small stations in New York, or of securing locations which will insure the company freedom from complaints due to the annoyance incident to such plants.

I think I have been slightly misunderstood. I do not advocate a multiplicity of plants, but I do advocate sub-dividing into a few plants, perhaps two or three, instead of building only one large plant.

As to the difficulty of securing sites in New York City, there is the site at Kingsbridge, 219th Street; the 96th Street location; the 74th Street; the 38th Street, and the 59th Street and North River. Five suitable locations have therefore been found by the large companies and I imagine the respective engineers each think they have the best site.

MR. TORCHIO:—The only stations the last speaker has mentioned are high-tension stations located on the water front. I wish to ask him if he meant that the New York Edison Company should have adopted several low-tension stations on the water front.

MR. LARDNER:—I suggested the advisability of two or three high-tension stations, not low-tension.

MR. TORCHIO:—Low tension stations would have been out of the question.

I want to take issue with Mr. Stott in his statement that the storage battery has no standing from the standpoint of saving station capacity. Under special conditions as in New York City, for the downtown district below Eighth Street, supplying the business section of the City, the load of the station is very light during the night hours until 8 A. M., at which time the load increases very rapidly and reaches a maximum about 9 o'clock,

and this load is practically maintained uniform throughout the day until about 5 P. M., when there is a very sharp peak caused by an overlapping of the motor and lighting load. This peak is of very short duration and shows a very sharp drop inside of the succeeding hour. A storage battery can be utilized advantageously at this time as capacity, in connection with the local low-tension steam-generating machines. Since after the load has gone through the sharp drop the battery is no more required as a reserve, thereby deriving the advantage of the battery as capacity without sacrificing the advantages of the battery as reserve during the day.

MR. STOTT:—At what rate do you discharge the battery?

MR. TORCHIO:—We discharge the battery at that period of the day at the maximum rate, the one hour rate. Where we have a lighting-load peak extending for three or four hours, as in the other districts, the result would be different. I have in mind the diagram of the power station of the Milan Edison Company in Italy, operating a transmission line from a water power plant and delivering a good deal of power for industrial motors and for running the street railway as well as lighting in the city.

The load diagram of the power plant, as I remember, is something like this, with a load factor of about 80 per cent. At this time (indicating), when they have the evening peak they discharge a very large battery, which takes care of the lighting load. They sell power in Milan in the neighborhood of $60 per h.p. and that battery, operated only for the few heavy load days of the year, enables the company to sell annually something like 2,000 to 3,000 h.p. additional.

MR. STERN:—Has Mr. Torchio any data as to the efficiency of that battery?

MR. TORCHIO:—The efficiency of the battery is of no importance as a commercial consideration. In the Milan plant supplying energy by water power, the losses in the battery are negligible, as to cost. What one has to consider are the financial results derived from the sale of 3,000 h.p. at $60 per annum, or $180,000 additional revenue.

The meeting then adjourned.

BRANCH DISCUSSIONS.

Discussion at Chicago, May 5, 1903.

Papers presented:

"Economical and Safe Limits in the Size of Central Stations," by H. A. Lardner. Abstracted by Prof. P. B. Woodworth, of Lewis Institute.

"Safety Devices in Central Stations and Substations," by Philip Torchio. Read by W. G. Carlton of the Chicago Edison Co.

"Multiple versus Independent Operation of Units and Central Stations," by Peter Junkersfeld. Presented by the author.

Mr. B. J. Arnold:—I am very much interested in the question of the production and distribution of power, but I cannot comment on these papers for the reason that I have not had an opportunity to read them. I think, however, that in general for lighting work or for power distribution in large cities, I would incline toward the single central-station where it could be economically located, as it usually can be, with the power distributed to substations containing rotary converters and batteries.

European practice seems to favor motor generators rather than rotary converters such as we use in this country. In Frankfort, Germany, I saw 1,000 kilowatt motor generators, of which the motors were single-phase, and the generators direct-current, running street railways very successfully, in conjunction with storage batteries, and this was soon after I had been told there were no large sinlge-phase motors running anywhere. The Europeans claim that they get better efficiency out of their combination of motors and generators than we do out of our combination of step-down transformers, and rotary converters, for the motor-generators utilize the incoming alternating current at the line pressure, without the losses of transformation.

When we use alternating current, however, as in railroad work, where we have to go across country long distances, I am in favor of divided power stations. It has only been within the last two or three years that I have preferred them, but my judgment now is that we shall run our railroads with power houses of moderate size, generating high potential, and located approximately 20, 30 or 40 miles apart. This eliminates a large part of the equipment we are now using, and brings down the first cost. It is in line, I think, with the recommendation of one of the papers of this evening.

Mr. W. L. Abbott:—Anyone who had the responsibility of supplying 1,000 tons of coal a day for power houses last winter would naturally have made up his mind long ago as to what was the most important feature of central-station operation. It is to get the coal there. To this part of the work my attention of late has been principally directed.

At our Harrison Street power house, which is now about ten

years old, the facilities for receiving coal were thought to be ample, since the Chicago River was on one side and the Alton switch tracks on the other. When the power house was first started fuel-oil was used, but that was soon abandoned and coal was brought into the boiler room by wheel-barrows; the wheel-barrow was superseded by a horse and dump cart, and later by a tramway with push car. Now we have automatic coal-handling apparatus and automatic stokers.

The cost of handling the fuel for all the labor connected with the boiler room has been brought down from about 40c per ton, under the first method—that is, with a wheel-barrow and hand firing—until now it is somewhere between 15c. and 20c. a ton. The difference looks like a very satisfactory saving, but it is probably larger than it should be, and on the consumption of 600 tons of coal a day, a saving of 10c. per ton would be very satisfactory.

In the larger power houses the matter of supply fuel is a serious problem. Some of the power houses now built and projected will require 3,000 tons of coal per day, which means perhaps two train loads. To get this amount of coal into the power house regularly is difficult. Storage facilities will have to be provided in the city for loaded cars, and means for shifting these cars about.

When dependence is placed on the railroads for rolling stock and for storage, there is continual complaint of unsatisfactory service. Therefore, a large power house should not only have storage tracks of its own, but undoubtedly rolling stock of its own. It should also have a large supply of stored coal nearby during the winter months.

There should also be coal and ash conveying apparatus and automatic stokers whereby the coal can be moved from the mine to the ash-dump without being touched by workmen. This not only for the saving of expense, but for the reducing of the number of unskilled employees about a power house, which, in these troublesome times with labor agitators, is an important matter only fully appreciated by those who have had to do with it.

Where there are several power houses in one system, the economical way is to run only the larger one as much as possible. Storage battery auxiliaries are also desirable.

It is absolutely necessary to meet promptly an increased demand for power caused suddenly by the formation of dark clouds, the breakdown of an adjacent power house or other similar circumstance. This is not difficult with hand-fired furnaces, but it is impossible with an automatic stoker. The latter takes its own time to get into condition for service. Most of the recent power houses are now supplied with blowers, which put an air pressure under the grates, whereby the amount of coal burned can be doubled or quadrupled.

The most wasteful pieces of apparatus about a power house are the boiler and furnace. The waste in them, counting the two

units together, may sometimes be as much as 50 per cent. of the fuel, and at least one-half of this waste is preventable. The operating engineer and designer should give their particular attention to the boiler and furnace, if great savings are to be secured. In a plant which is consuming two, three or four thousand dollars worth of fuel a day, a saving of even 5 per cent. would be a matter of very great interest to those who pay the bills.

MR. JUNKERSFELD:—I was interested in Mr. Arnold's remarks in connection with using a number of plants distributed twenty thirty or forty miles apart on a road through the country. It seems to me the number and distribution of such plants is dependent upon their size. For instance, if the load is heavy enough to require a fair-sized plant every thirty or forty miles, then perhaps it would be desirable to have them located about that distance apart. If, however, the plants are small, considerations of unproductive investment and unproductive labor would make it desirable to have them fewer and farther apart; that is, if still within the limits of economical high-voltage transmission, and if the reliability of service rendered is sufficient.

I fully agree with Mr. Abbott that the boiler room does not ordinarily receive the attention it should have, either in design or in operation. It must be remembered that the fuel and boiler room expense is a very considerable part of the total generating cost.

The use of forced draught to increase the generating capacity of the station in case of a sudden demand would often be very desirable. It would be the equivalent of storage battery capacity right in the boiler room, made available by starting the blowers. While this might involve either improved furnace construction or increased repairs to furnace and boiler setting, it would seem that a great deal of reserve capacity could be thus provided at a cost per unit of capacity less than that of storage batteries on a narrow peak. I do not mean that we are thus able to discount the value of storage batteries, which are distributed over the system and are, therefore, nearest the points where they can do the most good, but I do believe that under some conditions the use of auxiliary forced draught as reserve boiler capacity for sudden demands of short duration will be found advisable.

MR. H. B. GEAR:—I am chiefly concerned with the problems in connection with the 60-cycle, 2000 volt distributing system rather than the station and substation features of this discussion.

The principle of sectional operation has been generally applied to the 60-cycle distributing system in Chicago. The feeder system is operated separately; that is, a feeder supplies a section of the primary main system which is not interconnected with the mains of any other feeder, and that section of the city is, therefore, not affected by trouble in any other part of the city. In the same manner the secondary distributing system has been kept almost entirely separate. Each transformer, except in a few

cases where the load is very heavy, supplies a separate secondary usually about 800 feet in length. Interconnected secondaries are not desirable until the load reaches a density of about 40 k.w. per 1000 feet of line, or more.

MR. W. G. CARLTON:—I think practically all of the questions in connection with the high-tension, 25-cycle distribution system are treated by Mr. Torchio and I think he was wise in discussing only the electrical troubles and not referring to the mechanical ones. Considering cases of trouble occurring: Out of all the cases of trouble that we have had, here in Chicago on a 25-cycle 9000-volt system, fully three-quarters (probably more) occurred in the generating station and were mechanical; of the other one-quarter that were electrical, nearly all occurred in the generating station. The Chicago Edison Company has been operating at 9000 volts for about a year, and I do not recall now a single case of trouble that was due to a fault in the lines themselves, although one or two cases were due to the damaging of the lines by men working on them.

Mr. Torchio brought out the point of the separating of the lines for different substations. In accordance with this principle our down-town substations each have at least two lines—some more than two—and the machines in these substations are divided in two groups. In case of trouble at the generating station so that an engine has to be taken off and the 25-cycle load has to be reduced in a hurry, the operator knows exactly what lines to open, and in this way no one substation is shut down entirely. In a number of cases we have substations with batteries, and also with rotary transformers. In cases when it is necessary to reduce the load, the supply is cut off the substations where there are batteries.

There is another way that grounding the lead sheath of cables can be done in order to protect them from injury by stray current. This is by breaking the sheath at intervals, possibly every half mile, and grounding the sections at the middle point.

MR. ARNOLD:—I would like to ask Mr. Carlton if he has had any trouble with the breaking down of the insulation right where the cables leave the lead sheath?

MR. CARLTON:—We have had two or three cases not particularly serious—which were due to the ends of the cables not being suitably protected. We have since then taken more pains with the ends of the cables and have had no further trouble. Very careful work insulating the ends of the cable is required.

MR. CRAVATH:—In looking over the plans of several large steam-turbine stations which are under consideration at the present time, I have been impressed with the enormous amount of boiler room required in proportion to the turbine room. As one engineer put it, "I do not know but that we are coming to the time when we shall design our stations in the form of a number of radial units, each unit with a turbine in the middle and boilers on all sides of it." This humorous remark rather serves to call

attention to the fact that it is a nice problem in the designing of a steam-turbine generating station to preserve the symmetry of the station so it can be enlarged section by section, and at the same time get a large enough battery of boilers within reasonable piping distance of the turbine unit which they are to supply, without introducing objectionable features in the boiler arrangement.

MR. ARNOLD:—When I made my previous remarks I had in mind heavy trains, and when you consider a train that takes 1500 h.p. continuously you can have your stations thirty miles apart and have plenty of use for them if you have a number of these trains to pull. I should have expressed myself more clearly. On an ordinary interurban road with trolley cars, of course you would not need a power house every 20 miles, but when you consider the heavy trains, you will, in my judgment, need the segregated stations, and the complete elimination of the substations of step-up and step-down transformers.

COMMUNICATION AFTER ADJOURNMENT BY CARL SCHWARTZ.

The tendency in recent years is towards the erecting of single large power stations, not only supplying the growing demand for current, but absorbing smaller stations. It is evident that the arrangement of such stations must be made as perfect and safe as possible.

In the large modern central stations, even partial shut-downs occur very seldom, but influences of any kind affecting only a single part of such a station may lead to its complete shut down, while were the same aggregate power delivered from several separate stations, if one should be disabled the others would be able to maintain the service at least on part of the system.

The growing demand on the central stations has required the use of larger and larger generator units, but a practical limit in the extension of central stations and the size of units is soon reached. For this reason, it will be absolutely necessary to operate large systems in independent sections.

The most serious objection which could be made against independent operation of the generating units and the transmission systems is that the load cannot always be equally divided between the different units, and requires, therefore, a larger number in operation, some with uneconomical loads.

A suitable switching arrangement and a proper distribution of the feeder lines will, however, insure a reasonably economical load on all units, especially at time of heavy load.

The difficulty of uneconomical load with ordinary steam engines loses its importance with steam turbines whose efficiency we are told varies only about 3 per cent. from half load to 50 per cent. overload.

Independent arrangement and operation of generating units and transmission lines with a flexible switching arrangement, thus giving all the advantages of a large power station in erection,

operation and management, without running the risk of connecting these extremely large amounts of energy together continuously, is of great importance in the further development of large electrical distributing systems. The extension of large central stations and the extension of high tension distributing systems both at present limited in regard to safe operation, are practically unlimited with an independent arrangement.

The question of one or several power stations, located far apart from each other, but all supplying a common system, is often influenced by circumstances of peculiar kind and depends therefore in every case, on particular local considerations.

Discussion at Pittsburg, May 11, 1903.

The meeting was called to order by the Chairman, Mr. Lincoln, who introduced President Scott.

Mr. Scott made a few remarks concerning the proposed Union Engineering Building, and called upon Mr. C. W. Rice, Chairman of the Building Committee, for a statement regarding the present standing of the matter.

Mr. Rice gave a very interesting account of the efforts of the Committee to interest Mr. Carnegie, these efforts finally resulting in his offer of one million dollars for a Union Engineering Building. Mr. Rice said that great credit was due to both Mr. Scott and Mr. T. C. Martin for their persistent efforts to interest Mr. Carnegie.

Mr. Scott then opened the subject of the evening by a discussion on "Tendencies of Modern Central Station Development."

The papers presented at the New York meeting of May 24th were read in abstract.

Mr. Hodgkinson:—In the paper by Mr. Lardner reference was made to steam turbines applied to large central stations. There is no doubt that steam turbines are every day establishing themselves as reliable units.

The difficulty of multiple operation of alternators as pointed out by Mr. Lardner is entirely at an end. I know of four 400 k.w. Westinghouse turbines at the Westinghouse Air Brake Company's works having a 2½ per cent. variation of speed between no load and full load, and whose parallel operation through all variations of load has never left anything to be desired.

Some comparisons have been made of floor space occupied by turbines and it has been shown that the Curtis turbine, by reason of its main shaft being vertical, occupies less floor space than the Westinghouse turbine. If, however, we consider the cubical contents of the machine, this difference in some cases disappears and in others is much less in evidence.

Another point, however, should not be lost sight of, that by reason of the shaft being vertical and having considerable top weight it would be supposed that much more massive and better foundations are necessary than would be the case with the shaft horizontal.

A turbine and generator with horizontal shaft needs substantially no foundation at all, only something that will hold the dead weight of the machine. They may be placed on the upper floors or the roof without in any way interfering with their operation.

The economy of steam turbines has also been well established and I would cite a few examples of tests on various machines lately taken in the Westinghouse Machine Company's works.

RESULTS OF TESTS ON WESTINGHOUSE PARSONS STEAM TURBINES.

In the tables below are given boiler pressure (b.p.), brake horse power (b.h.p.) or electrical horse power (e.h.p.); total weight of water per hour, and weight of water per electrical or brake horse power.

400 K. W. 135 B. P. 27″ Vacuum.

B. P.	Vacuum.	B. H. P.	Total Lbs. Water.	Water Rate.
137.6	27	624.6	9319	14.92
136.0	27	516.2	7852	15.21
138.0	27	390.7	6236	15.96
144.0	27	6.3	764	.....

400 K. W. 135 B. P. 26″ Vacuum.

B. P.	Vacuum.	B. H. P.	Total Lbs. Water.	Water Rate.
143	26	623.4	9502	15.24
144	26	508.2	7992	15.73
144	26	381.0	6311	16 56
138	26	10.7	1035	.....

400 K. W. 155 B. P. 100° Superheat. 28″ Vacuum.

B. P.	Superheat.	Vacuum.	K. W.	E. H. P.	Total Lbs. Water.	Water Rate per E. H. P.
150.4	99.6	28.150	412.50	553.00	7498	13.55
152.6	102.3	28.123	312.80	419.30	5797	13.83
152.6	102.0	28.200	209.70	281.07	4140	14.73
152.0	58.6	28.200	113.35	151.95	2745	18.06

1000 K. W. 150 B. P. 28″ Vacuum. Moist Steam.

B. P.	Moisture.	Vacuum.	K. W.	E. H. P.	Total Lbs. Water.	Water Rate per E. H. P.
140.2	2.3	28.36	961	1288.1	20251.0	15.70
140.3	2.0	28.33	756	1015.0	16617.0	16.35
145.0	1.6	28.30	481	645.0	11903.6	18.45
145.0	1.8	28.48	250	3355.0	7656.0	22.80

1500 K. W. High Vacuum.

B. P.	Per cent. Moisture.	Vacuum.	K. W.	E. H. P.	Total Lbs Water.	Water Rate per E. H. P.
148.8	1.2	27.92	1545	2065	30456	14.73
149.9	2.5	28.12	935	1252	19703	15.75
151 8	2.1	28.98	262	349.0	7392	21.80

Same Machine.

B. P.	Superheat	Vacuum	K. W.	E. H P.	Total Lbs. Water.	Water Rate per E. H. P
154.6	140.6	28.10	1512.0	2030	25686.0	12.66
149.5	138.9	28.04	904.0	1210	17042.8	14.10
148.9	138.4	28.20	306.2	412	8108.6	19.68

Turbines of the type mentioned above being very simple affairs require but little erection, and it is a simple matter for them to be thoroughly tested in the builder's works.

The advent of the steam turbine in large central stations will probably involve some changes of detail in the auxiliaries. The gains in economy due to operating with high vacuum demands a higher type of condenser than those ordinarily employed. The fact of the turbine being able to avail itself of all the advantages of superheat while exhibiting none of its disadvantages will usually make the consideration of superheaters desirable. A steam turbine is more economical than a reciprocating engine principally because it is able to make use of the expansive energy of steam down to lower limits than is practicable with reciprocating engines. The comparatively low friction losses of a turbine enables it to hold up its high economy over a wider range of load than is possible with a reciprocating engine.

The demand for high class condensers is met by the employment of surface condensers equipped with tandem cylinder rotative dry vacuum pumps for dealing with the air, and a small duplex independent pump for dealing with the water. This latter pump delivers into the hot well from whence the feed pumps draw their water, which may be a sealed chamber, such that the steam, from leaving the boilers, to being returned to them as feed water, never comes into contact with the air and does not become ærated, thus leaving the air pump little to do except taking care of a small unavoidable leak in the exhaust piping.

To make a comparison of the effect of vacuum, a test on a 1500 k.w. turbine shows the following:

25″ Vacuum = 16.5 lbs. per Electrical H.P. Hour.
26″ " = 15.8 " " " " "
27″ " = 15.3 " " " " "
28″ " = 14.8 " " " " "

with 150 lbs. boiler pressure. Moist steam.

The effect of superheat is to increase the economy not less than 7 per cent. for 50° superheat, 10 per cent. for 100° superheat, and 12½ per cent. for 150° superheat.

What will be the limits of superheat that may be employed is hard to determine, but I imagine the limit will be reached in the superheater itself as soon as in the turbine.

The reason why superheat makes such material gain in economy is probably because it reduces the amount of water in the expanded steam due to adiabatic expansion.

It is also probable that the heat added to the steam in the shape of superheat is nearly all available for useful energy, which is not the case of the heat used in evaporating the water in the boiler, as but a small percentage of the latent heat is given up in the shape of energy in an engine. There is no doubt the cost of attendance and oil with turbines will be much less than reciprocating engines, and there is little doubt that steam turbines will continue to be employed more and more.

In reply to questions by Mr. James and Mr. Lincoln, Mr. Hodgkinson gave the following information.

Turbines of the Parsons type built by the Westinghouse Machine Company do not lend themselves well to design in very small powers. For that reason machines less than 200 or 300 k.w. are not encouraged. For sizes larger than that the steam consumption may generally be said to decrease with the size.

For driving electrical machines, in which the number of poles and standard frequencies are of such nature that the number of poles being very few, the intervals between standard speeds are very large. For instance, with standard frequency of 60 cycles there is no intermediate speed between 3600 and 1800 r.p.m. With other periods, such as 25 cycles, which is used for power work exclusively, we cannot get higher speeds than 1500, which requires a two-pole generator. It thus happens in the design of turbines we get uncomfortable speeds.

MR. ETHERIDGE:—One of Mr. Lardner's remarks did not favorably impress me:

"Frequently the business in the individual towns would not be large enough to permit of an independent plant in each, and any risk of interruption to service is put up with because it is the best kind of service that such a community can support."

That seems to me to be a reflection on the electrical engineer. I do not see why a small town should not have just as good service as a large city. It is a question only of the proper construction of transmission lines; a matter thoroughly discussed at the last meeting of the INSTITUTE.

MR. RICE:—Mr. Rice spoke of the experience he had had in central station work when connected with the New York Edison Company. He spoke of the excellent record of the New York Edison Company for continuity of service, as in twelve years' time current had never been entirely off their circuits. Mr. Rice stated that in his judgment the direct current possessed many

advantages over alternating current for distribution in a large city. The two most important advantages are that it permits the use of storage batteries and under certain conditions is better for operating motors. In all of the large cities the storage battery is used not so much as a means for carrying the peak of the load as an insurance against shut down. Central stations in all of the large cities are supplied with storage batteries of sufficient size to carry the entire load for short periods without assistance from the generating apparatus.

A case was cited where seven 1,000,000 c.m. cables were burned off on account of a short circuit, and the chart at the station showed a variation of but 1½ volts, thus showing the great steadying effect of the storage battery on the system.

As soon as one leaves the central station he gets into the mesh system of conductors, so that in case of trouble there is relief from every direction. At frequent intervals in New York City there are generating stations or rotary substations having storage batteries of large capacity. This insures absolute continuity of sevrice.

The conditions essential to the obtaining of a high load factor was referred to. Attention was called to the methods of Mr. P. G. Gossler of Montreal, who by granting special rates on power at certain times of the day had created a large demand for power between 4 A.M. and 4 P. M., thus obtaining an extremely high load factor.

The importance of safety devices for maintaining continuity of service was also referred to.

MR. LINCOLN:—In confirmation of Mr. Rice's statements in regard to batteries, I was talking some weeks ago with one of the New York Edison Company's engineers, during which conversation he stated that his company's aim was never to have the batteries discharged. They were kept practically full all the time, so that in case of accident to the generating machinery, the batteries would be prepared to take the load. The batteries are used practically as safety devices, rather than to reduce the load on the generating station, for which purpose batteries are very often used.

Another point, and one which Mr. Rice did not bring out, is the fear on the part of the operators of large low tension systems, such as the one in New York, is that if power ever does get off the mains, it will be very difficult, if not impossible, to get it back on. The net-work of mains is fed by some ten or fifteen different substations. A single substation would not begin to be able to carry the load and it would be practically impossible to have all the substations thrown into the system simultaneously.

The engineer to whom I was talking cited a case in Milan, where there is also a large low-tension net-work. In this case he said that the power went off his net-work and the difficulty, as noted above, was experienced in getting the power back on to the net work. It was necessary finally to cut the net-work up into

sections, and this cutting up of the net-work required nearly three days. The power was off of parts for all that time. This is one of the dangers to which a large low tension system is liable and is what the New York Edison Company is striving to avoid by keeping their batteries prepared at all times to assume the total load independent of any generating system.

MR. SCOTT:—I take exception to the broad statement that "the way to maintain continuity of service is to have safety devices"—there may be too many. I know of a large company which installed a great many safety devices and had troubles at various times. After the plant had been running for some four or five years, I made a remark one day to the engineer in charge that most of their troubles had been due to their safety devices. Although the safety device is intended to prevent accidents, it is itself often the very source of accident and of trouble. This is one of the reasons why the fuses have been left out between alternators and bus bars. Fuses, particularly for high voltage or for heavy current, are disagreeable adjuncts to a station equipment. In general it is not good practice to put in a line anything that can be avoided.

Meeting adjourned.

DISCUSSION AT ST. LOUIS, MAY 16, 1903.

The meeting was called to order at 8.30 P. M., at the Engineers' Club, W. E. Goldsborough, Chairman, presiding.

Announcement was made by Secretary Swope of Mr. Carnegie's gift of $1,000,000 to the Associated National Engineering Societies. The Secretary spoke of a local movement for the same object. Mr. Goldsborough made some remarks in regard to the same matter, also in regard to the INSTITUTE Building and the better standing it would give to the profession of engineering throughout the country.

Announcement for the next meeting was then made, also for the annual meeting at Niagara.

The papers for the evening were:

No. 1.—"Economical and Safe Limits in Size of Central Stations," read by Mr. Dyer.

No. 2.—"Safety Devices in Central Stations and Substations," read by Mr. Langsdorf.

No. 3.—"Multiple versus Independent Operation of Units and Central Stations," read by Mr. Klauder.

The salient points of the discussion at the New York meeting were read by the Secretary.

The papers were then opened for discussion, in which Mr. E. D. Matlack participated, whose company is now installing a 500 kilowatt General Electric generator, connected to a Curtis turbine. Much discussion was brought out in regard to the question of the advantage of superheating the steam.

Mr. Borden spoke at length on the same subject.

Mr. Welz, Director of the Word's Fair, told of waste heat engines, which have been largely advanced in Germany, but not used in this country. He said:

I should like to draw your attention to some new features of modern development of central stations brought out in Germany. When in Berlin last September, I visited the central stations in Markgrafenstrasse where a new type of engine, a so-called "sulphurous anhydride waste-heat engine," was running. The reason for the construction of these machines was the low thermal efficiency of the steam engine which is, in the best machines, only about 23 per cent. The purpose of the waste-heat engine is to use the heat which is generally lost in the exhaust steam for vaporizing a liquid with a low boiling point of which the vapors under the given temperature have already a very high pressure. With these vapors a new engine can be driven. Of all the liquids which can be employed for this process, the sulphurous anhydride (SO_2) has proved to be the most practical.

The general scheme of the engines is very simple. The exhaust steam of the steam engine is conducted through a surface condenser which serves as a vaporizer of the SO_2 liquid. At a temperature of 150° F., corresponding to the temperature of steam in an 80 per cent. vacuum, the sulphur dioxide vapors have a pressure of 156.5 lbs. per sq. in. abs. These vapors then enter the waste-heat engine, which is similar in construction to a steam engine. The sulphur dioxide vapor leaves the engine at a pressure of 4.8 lbs. per sq. in. abs. and passes on to a second surface condenser, where, by means of circulating water, it is again liquified. A small pump delivers the liquid sulphur dioxide from the condenser back into the evaporator or the exhaust-steam condenser, where it is ready to repeat the cycle. Hence, neglecting the losses through possible leakage, the working medium is used over and over again and requires no replenishing. The only difficulty in the construction of these machines was to have the stuffing box of the piston-rod tight. After some experiments this difficulty was entirely overcome and Prof. Josse, the constructor of the machines assured me, when I saw him in Berlin, that the machines as now constructed are perfectly satisfactory. The waste-heat engine in the Markgrafenstrasse develops 175 h.p., using the exhaust steam of a 360 h.p. vertical compound steam engine, and thus adds 48.6 per cent. to the energy produced by the steam engine. The cost for such a waste-heat engine is about equal to that of a steam engine of the same size. It is therefore easily seen that in this way the efficiency of electric central stations can be largely increased.

At the present time there are a great number of such waste-heat engines in use or under construction; as an example of the modern construction of these machines, I can show you a picture of a 200 h.p. and a 450 h.p. waste-heat engine, the first built by the Maschinenfabrik Sulzer the latter by the Goerlitzer Maschinenbauanstalt. The waste-heat engines for the utilization of

exhaust steam are now entirely worked out as turbines as well as piston engines. Trials have been made lately for the utilization of flue gases of boilers, blast furnace gases, exhaust gas of gas engines, etc., and these trials give satisfactory results, but the company which exploits these patents is not yet ready to put the machines on the market.

I should like to show you a very interesting diagram; you see here upon the upper side of the drawing the general disposition of a steam plant: boiler, steam engine and waste-heat engine; the diagram below shows in per cent. of the heat energy produced in the boiler the amount of energy developed in the steam engine and in the waste-heat engine and the losses which occur during this process. According to this, 12 per cent. of the original heat is utilized in the steam engine and 4 per cent. in the waste-heat engine; 2 per cent. is lost in the ashes, 7 per cent. by radiation from the boiler, 22 per cent. goes in the flue gases, where 6 per cent. is recovered by the economizer and 16 per cent. escapes through the chimney, 2 per cent. is lost in the piping from the boiler to the steam engine, 2 per cent. radiated from the steam engine, $1\frac{1}{2}$ per cent. in the steam piping to the vaporizer and $53\frac{1}{2}$ per cent. is lost in the cooling water.

Discussion at Philadelphia, April 6, 1903.

Mr. Hodges:—A few items of particular interest were brought out in the discussion at New York, so I will quote from that discussion.

Mr. Hodges:—Mr. Gerry wrote, "There is no special difficulty in installing a successful telephone circuit, which will give satisfactory service and reasonable safety in operation, on a pole line carrying from 50,000 to 60,000 volts." With this I heartily agree, and many would undertake to install a successful system in connection with any present high tension transmission line without the slightest doubt of success. It simply amounts to taking the necessary precautions to have the line properly ballanced, insulated and protected. But I cannot agree with Mr. Gerry that "the ordinary telephone lightning arrester is an undesirable and unsafe piece of apparatus for this purpose," —referring to a location "where there is considerable lightning." Of course, he says *ordinary arrester*, and this brings up the question to what arrester does Mr. Gerry refer? I have had considerable experience with different types of arresters and I have found that under the conditions mentioned by Mr. Gerry, some arresters are better than others. Unfortunately, we do not know just how a lightning discharge will act in every case. Lightning discharges are freakish, but a properly constructed telephone system will be as safe as anything possibly can be. Of course, the *ordinary* telephone lightning arrester would not be sufficient in *extraordinary* cases.

Mr. Mershon stated that the truth of the observations of para-

graph (6) of Mr. Lincoln's paper was not apparent to him. Referring to the first portion of this paragraph, in which Mr. Lincoln states that comparing the electromagnetic and the electrostatic disturbances in the section of untransposed telephone lines, the first is in the nature of constant *potential* effect, and the second in the nature of constant *current* effect.

Mr. Mershon agrees that the electromagnetic disturbance is in the nature of constant *potential* effect, but does not agree that the electrostatic disturbance is in the nature of constant *current* effect, excepting only when the static charge carried by the telephone circuit approximates that which the power line can impress statically upon the telephone lines. This is not actually the case in practice, so the electrostatic disturbance is also in the nature of constant *potential* effect. Therefore both effects are of the same nature, " that of constant voltage under actual conditions."

Mr. Lincoln's view of this matter seems to me to be that as the electrostatic charge on the two telephone wires is not independent of the resistance of the telephone circuit, an increase in the resistance of the circuit will increase the electrostatic charge to the telephone wires, and this increase of charge will tend to overcome the increased resistance and maintain a constant current effect.

However, in any particular instance the resistance will remain constant, and I agree with Mr. Mershon that both the electromagnetic and electrostatic disturbances would be in the nature of constant voltage effect.

Mr. Mershon further said that the statement of Mr. Lincoln's with respect to the disturbing ampere-turns was incorrect, " if, by telephones of various resistances, it is meant to designate telephones of various number of turns, assuming the same space available for copper in each case." Mr. Lincoln states that "with telephone receivers of varying resistance, the ampere-turns in the receiver due to electromagnetic induction, are particularly constant, while those due to electrostatic induction increase with the number of turns and, therefore, with the resistance of the receiver."

Mr. Mershon's objection is that with constant potential the ampere-turns are not constant as the resistance increases, as the ampere-turns vary inversely as the square root of the resistance. I agree with Mr. Mershon in this, but perhaps Mr. Lincoln does not refer to the increase in ampere-turns under the assumption that only the same space in each case is available for copper.

I would say, however, that while the electromagnetic induced e.m.f. is independent of the resistance and the electrostatic induced e.m.f. is dependent upon the resistance, the effect of both upon the receiver is dependent upon the number of turns of the receiver; the electromagnetic induction by reason of the number of turns and the resistance, and the electrostatic induction for the same reasons and also because of the effect upon the electrostatic e.m.f. by the change in resistance, when the resistance is low.

And so, comparatively, the electromagnetic disturbance in general is more greatly reduced by an increase in the resistance of the receiver on a similar coil, than the electrostatic disturbance.

Mr. Mershon said that from the above conditions it would seem advisable to wind the receivers to as high a resistance as possible, in order to overcome the electromagnetic and electrostatic disturbances. This is evident; but assuming that the ordinary telephone receiver for various reasons is as large as desired, there is a mechanical limit to the increasing of the resistance.

It has been supposed throughout, that the receiver is connected in the line direct. This, however, is rarely the case. Most often the receiver is connected to one side of a transformer (or "repeating coil," as we term it), and the other side of the transformer is connected in the line. This transformer could be built to any desirable size and resistance, particularly as it is advantageous to raise the potential in transmitting, and therefore the number of turns of the winding connected to the line may be large.

Mr. Mershon stated that the objection given for the use of the series telephone by Mr. Lincoln does not seem a valid one, as no one would connect either a series or bridging telephone at a transposition point. In his paper Mr. Lincoln has only taken the worst point as a sort of "horrible example."

I would say, however, that from consideration of the static disturbance, which is twenty times or more greater than the induced current disturbance, a series instrument could not be connected in the line without throwing the system out, except at certain points; and these points are the ones from which no induced charge is flowing towards a transposition point. Moving the instrument from these neutral points towards the transposition points, would simply be going from good, through bad, to worse. An instrument bridged across the line would not be disturbed to any extent as a path of least resistance would be toward the transposition point, and not through the coils of the instrument.

In the discussion, Mr. Lincoln attributes his trouble with series instruments largely to the points of contact. This could easily be a cause, but the principle trouble would come from the above-mentioned static disturbance. Mr. Mershon suggested a method of accomplishing the desired end of having the telephone lines as nearly as possible at the same potential as the earth, which, he says, seems preferable to the use of a ground wire suggested by Mr. Lincoln in paragraph (15). Mr. Mershon's method is that of using auto-transformers connected across the telephone line at a number of points, preferably at each of the telephone stations, each having its middle point connected to ground. He goes on to say that each transformer should be designed so as to take up a small amount of telephonic current, but should have wires of sufficient size to enable it to take, in case of a cross with a high voltage wire, a current heavy enough to operate the circuit opening devices in the power stations, or else to blow a suitable fuse in

the telephone circuit itself. If the transformer designed to allow a passage of sufficient current to blow a fuse would also prevent the passage of the telephonic current, it appears to me that the idea is a good one. But, referring to the case where the power circuit is of high frequency, the transformer coil which would prevent the passage of the telephonic current would also retard the passage of the power current, and it would be necessary to protect the telephone user and open the line by other means.

Mr. Thomas suggested that probably the increasing of the capacity between the ground and telephone wires might best be accomplished by using a twisted pair, one side of which is connected to the ground, for each side of the telephone circuit; and having this properly insulated would prevent the danger of a cross such as would be likely to occur. Mr. Lincoln's scheme is that a wire connected to the ground be run in proximity to the telephone wires, all of which, presumably, would be bare. Mr. Thomas's idea would be carried out at less expense by using triple conductor-wire. Of course, if a lead-covered cable would be used, the grounding of the sheath would carry out Mr. Lincoln's idea completely. This, however, would increase the expense of the line considerably.

All these methods of bringing the ground near the telephone wires would make it much more liable for a workman to ground the telephone wires through his body, and therefore, as suggested by Mr. Thomas, he should be protected by having, between the telephone circuit and ground, an air gap small enough to make it safe.

Mr. Lincoln's objections to the introducing of transformers, condensers, resistances, etc., between the telephone wires and ground are recognized by all who are particularly interested in having the telephone system work as well as it possibly can. The line should have as little leakage as possible and the capacity of the telephone lines should be kept as low as may be. Therefore, to obtain the best transmission with the greatest safety, it would seem that the following points should be carefully considered:

First:—Both power and telephone lines should be properly transposed. And this transposing is not altogether as simple a matter as it is generally supposed, as it would be possible to arrange the transpositioning so that the power and telephone wires would neutralize each other.

Second:—The insulation of the telephone lines should be high, and of course the line should be strongly constructed.

Third:—At each telephone station the instrument circuit should be connected to the secondary of a transformer. This transformer should have a high resistance primary with a great number of turns, and the insulation between the primary and secondary should be high. The middle point of the primary should be connected to ground through a retardation or choke-coil. In each side of the telephone line circuit, at each station, there should be a so-called "lightning gap" arranged; designed

so as to discharge when the potential of the telephone wires should approximate that which would break down the insulation of the line.

In the connection to ground of this lightning arrester, there should be placed an electromagnet of low resistance and low retardation; so arranged that by its operation it will open the telephone line between the arrester and transformer and connect the ground side of the lightning arrester with the ground direct.

This method of construction removes the objection that a workman would come in close proximity with the ground while working on the telephone circuit. And also it provides necessary protection for the telephone user without allowing a path for leakage of the telephone current, or affecting the transmission by increase of capacity.

MR. LINCOLN:—In reference to the telephone business, it has been the general experience that as long as no trouble occurred on the main transmission line paralleling the telephone line (or rather which the telephone line parallels) the service on the telephone line can be carried on with practically no difficulty. As soon as the main line gets into trouble by grounding, and so on, there is difficulty on the telephone line—it becomes very noisy and practically inoperative. That is just the time when the telephone line is most important; when there is trouble, you want to use the telephone line.

H. H. BARNES, JR.:—There are one or two points in connection with Mr. Lincoln's paper that may possibly be of interest. Take a three-phase transmission line and ground one wire; you get an unbalanced static condition on the line, and in doing that, if the insulation is not exceedingly high, it will break down practically every time. It may be that this effect can be traced to the charging current, but if the same wire is grounded at the other end of the line and a current sent through it equal to the charging current, it would be found that this current would by no means have the same effect that charging the line to the normal voltage would have. If the telephone line has resistance to the ground it is pretty sure to give way somewhere. I have noticed in transmission lines using the Scott connection—which when the load comes on, means a certain amount of unbalancing—a slight voltage due to magnetic action. Taking the telephone line, and the earth as the other side, if, under those conditions due to the Scott connection, one end is grounded and the voltmeter is connected from the other end to ground, there will be found a small voltage, depending upon the amount of unbalancing.

There is also another point that may be of interest. If there is a long stretch of transmission line in which the power wires are not transposed, and the high voltage side of a transformer is connected between the two telephone wires and ground, and lamps are put on the secondary side of this transformer,—if the line is long enough these lamps will usually burn. This may seem rather paradoxical, as there is no return circuit. This is between

the earth and the telephone wires. The voltage naturally between the telephone wire and the earth depends upon the constants of the construction of the line and not upon the length of the line itself. But the intensity of the effect will vary a good deal. Very possibly the effect will not be strong enough to make the lamps glow.

CHAIRMAN HERING:—We would be glad to hear from some of the insurance men.

WASHINGTON DEVEREUX:—Naturally, insurance people are not in favor of high-tension currents beyond five hundred volts. High-tension has come to stay. In the early days I think the electric light people frightened the insurance people very much. The subject is now in safe hands and being considered in conjunction with the Committees of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS and the National Board of Fire Underwriters, and I think very soon there will be rules formulated permitting sixty thousand volts. Those rules have not yet been published, and what they are I don't care to say.

CHAIRMAN HERING:—I wish to call attention to a limitation of the formula of Mr. Mershon, which is, I believe, the well-known formula for beams. While it is correct, it should be understood that it applies only to the case in which the cross-section does not change abruptly. For instance, if in a thick horizontal projecting beam a vertical saw-cut is made, say half way through it, the beam will not be as strong as a smaller beam having a uniform cross-section equal to the remaining half. In other words, a beam of small but uniform or uniformly varying cross-section may be stronger than one of larger but abruptly changing cross-section. The shoulder of the proposed standard pin is a case of this kind, in which the cross-section changes abruptly and this changes the internal stresses in such a way that the pin may be subjected to much greater strain than this formula would give, unless the bracing action of this shoulder more than compensates for the abrupt change of cross-section.

Mr. Mershon proposes to cut off the tops of the screw thread, as shown in his illustration; why does he not also fill up the bottoms of those V-shaped screw thread cuts, as is done in the standard thread? This would make the pin much stronger, as there is then a less abrupt change of cross-section. It would also be interesting to know why he used an angle of 90° instead of 60°, as in standard threads.

CHARLES HEWITT:—I notice that in this pin, which I believe is one of Mr. Mershon's, the bottom of the groove is flattened. It seems to be flattened just as Mr. Hering says.

CHAIRMAN HERING:—We have a number of models here that have been sent to us by the manufacturers. Mr. Sanville will tell us something about them.

(Exhibition of specimens of insulators and pins.)

MR. HUTCHINS:—I would like to ask if anyone here has had experience with benefits derived from using a dark color over a

white porcelain. I have heard it said that the white porcelains make a very good target, while the dark ones are not so conspicuous.

CHAIRMAN HERING:—Someone remarked that the insulators would be liable to crack when the sun shines on them. It seems to me that the dark one would be much more liable to crack from the sun than would the light one.

MR. LINCOLN:—I think the porcelain insulators will stand the strain due to heating much better than the glass. As far as shooting is concerned, I think the brown insulators were adopted at Niagara on the last installation there for the purpose of being less conspicuous, although we had no very great trouble there.

MR. HODGES:—The question of shooting insluators is of great concern to the telephone people. A small boy seeing the insulator shoots at it and puts shots through the ærial cable, which very much disturbs the ærial cable. At Niagara it seems that small boys throw hoops over the wires, short-circuiting them and causing "fireworks."

MR. LINCOLN:—Shooting insulators reminds me of a story in reference to the lines running into the City of Mexico. They have a great deal of trouble there from the fact that the natives throw the leaves of a plant called the megalia, which is a plant consisting of ninety-nine per cent. water, over the lines, and they cause a great deal of trouble, so much that they had to get the Governor to detail a cavalry guard. One day they caught a native throwing leaves. They took him to court, proved the case against him and the judge sentenced him to a year in jail. He suspended sentence, however, until the next case of malicious interference, no matter who caused it.

MR. HEWITT:—In Mr. Sanville's abstract of the New York discussion he spoke of the "digested wood" as being fine nitrogen salts. I would like to ask whether there was any explanation as to how these nitrogenous salts were formed, whether the air in the neighborhood was combined with the air forming nitric acid, or how that combination came about.

MR. SANVILLE:—As I understand Mr. Buck's description of this, he seems to take for granted that we all know that a static discharge in moist air produces nitric acid. It seems to be a fact he is aware of.

MR. HEWITT:—I have learned something new. I was not aware that nitrogen and oxygen in the air could be combined to make nitric acid.

CHAIRMAN HERING:—There is a plant in operation at Niagara Falls where nitrogen and oxygen are combined, forming nitrous oxide gas from which nitric acid is made.

MR. HEWITT:—There is one other point in the discussion in which it says ecualyptus pins are found the best. Naturally that would be the case in California as there are no others in the state. But it is hardly just to claim that it would be better than the locust or the oak.

MR. THOS. SPENCER:—In regard to the formation of nitric acid, even an arc, in a confined space in the presence of water will form nitrous acid. Take an enclosed lamp after burning a short time and shut it off and after a while open the cylinder; you would get a very decided nitrous acid smell. That is probably what Mr. Buck referred to.

CHAIRMAN HERING:—It seems rather a difficult thing to do to combine the oxygen and nitrogen in the air. It seems a peculiar case in which it is done unknowingly or unintentionally.

The meeting then adjourned.

DISCUSSION AT CHICAGO, APRIL 7, 1903.

The meeting was called to order at 8.20 P. M., with Secretary Pierce in the Chair and about 100 members and guests present.

The first paper, "Mechanical Specifications of a Proposed Standard Insulator Pin," by Ralph D. Mershon, was presented by Mr. W. G. Carlton.

At the conclusion of the reading of the paper, Mr. Carlton also read a discussion which had been presented in New York, by Mr. C. L. Cory, of San Francisco, and D. L. Huntington, of Spokane, Washington.

The second paper, "The Testing of Insulators," by F. O. Blackwell, was presented by Mr. James Lyman.

At the conclusion of the reading of this paper, Mr. Lyman read a portion of the discussion which had been presented in New York, from Mr. M. H. Gerry, Mr. P. M. Lincoln, Mr. W. N. Smith and Mr. C. C. Chesney.

MR CARLTON:—I remember a test made on a lot of 5,000 glass insulators, at 50,000 volts; out of that lot a very small number broke down—in the neighborhood of five, I think—and a part of the defects in the five could have been detected by examination. Of this lot of 5,000 insulators which were put in service on a 33,000 volt line only a few have broken down, and they were probably injured at the time they were installed.

MR. GONZENBACH:—I think the matter of glass versus porcelain insulators has been agitated for a good many years.

Mr. Carlton seems to be in favor of glass insulators, and in the particular instance that he refers to, I would like to ask if the glass insulator had been tested at the factory or on the ground before being put in service?

MR. CARLTON:—I do not know about that; I simply remember the results that we obtained.

MR. GONZENBACH:—I have had that question before me for about eight years, and in every plant I have been connected with this question has come up, whether glass or porcelain insulators should be used.

I was at one time connected with the building of a small municipal plant in the east—in Vermont. Every purchase was passed upon by an assembly of voters of the town, and it was

interesting to watch those old farmers discuss whether glass or porcelain insulators were the better; there were some red hot arguments on both sides, but I do not know that I am any nearer a decision to-day than I was at that time. I think the disrepute of glass is very largely due to the manufacturers of it. I can only say that so long as power is transmitted over glass insulators at between 40,000 and 50,000 volts glass insulators must be considered as competitors of porcelain.

Mr. Blackwell mentions a factor of safety of about 3½ to 1, in connection with the very high pressure test, and a maximum test pressure of double the service pressure. I cannot understand why we should go quite so high. As a matter of fact I understand that Nunn Bros., in their Telluride, Utah, installation, using 40,000 volts transmission pressure, give their insulators a test not exceeding 50,000 or 55,000 volts, and are obtaining good results.

The third paper, "Transposition and Relative Location of Power and Telephone Wires," by P. M. Lincoln, was presented by Mr. H. H. Wait.

At the conclusion of the reading of this paper the discussion which had been presented in New York by Mr. M. H. Gerry, Mr. Ralph Mershon and Mr. Thomas, was read.

MR. WAIT:—Mr. A. S. Hatch, City Electrician of Detroit, has had trouble on account of induction on their telephone lines, which are run on the same poles, in a good many cases, as their series arc-lighting lines. These arc-lighting lines are, of course, not of the very high potential character which we have been talking about, but the fact that they are constant current and have varying resistance in the circuit, brings up a little different problem. He has sent a communication and I will read some parts which will perhaps be of interest:

MR. HATCH:—I have been greatly interested in the introduction for discussion of disturbing currents in telephone lines, particularly on account of my own experience during the past year with series alternating arc lamps supplied from circuits run, in places, on the same poles with fire alarm and police telephone systems.

When the plant of the Public Lighting Commission of Detroit, Mich., was installed, it consisted of direct-current open arc lamp, burning in circuits of 100. Two years ago in order to meet the demand for new lamp locations, it was decided to install the series alternating arc system, and the first installation was in the western part of the city, consisting of about 380 lamps supplied by six circuits from a substation which received the current from the main station by means of a two-phase feeder, thus giving three circuits in multiple on each phase, each circuit being controlled by a reactance coil. The old direct current circuits were not changed except to cut them into the substation, reduce them to 60 lamps capacity and double all single wire loops. Where convenient, at the time of installation, the lighting commission, fire alarm telegraph and police signal systems were run on the

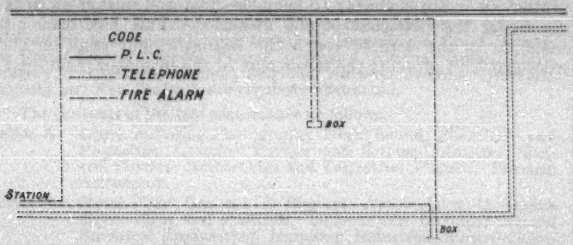
same poles. About one-half of this combined construction consists of a six-pin arm with the arc circuits occupying the middle pins and the fire and police wires on the outside, the remainder being the commission wires on an arm below the fire and police. The combination of any particular arc and fire or police circuits is only for short distances, one or the other circuit frequently leaving its neighbors on its own poles and if coming back again it may be to meet another arc circuit of a different phase. The six circuits are designated by letters. The least induction is produced when the circuits A, B and C are of one phase and D, E and F of the other, although they are so arranged that any circuit can be run with either phase. However, if C and F are cut off, the telephone lines are almost silent, showing that where the fire and police lines parallel the other four circuits, they balance themselves. This made the first problem to balance the telephone lines for circuits C and E and, at the same time, not disturb the balance already established in connection with the other four.

Having accomplished this, cleared the telephone lines from electromagnetic induction, but a change in the electrostatic capacity of any circuit would alter the conditions entirely. The alteration of the electrostatic induction is produced in three ways: first, by the leakage of both the arc and telephone circuits, due principally to dampness; secondly, by varying resistances particularly in the arc circuit; thirdly, by the disturbance due to independent parallel lines. The arc circuits, when running, will vary in insulation from 500 to 150,000 ohms between wires and ground, yet, on battery test the next day will measure over a megohm, I am satisfied from tests conducted so far that the increased induction caused by this variation can be eliminated by the proper use of condensers and inductances. The second variation, that due to a variation of the resistance of the arc circuit is entirely a lamp variation and will be corrected in the lamp.

The third disturbance, that due to independent parallel lines, is the most serious one to overcome. By independent parallel lines, I mean any wire paralleling an arc circuit and constituting, in itself, a closed circuit. My attention was first called to this about three years ago. The arc circuits are grounded at the switchboard during the daytime, so constituting a closed circuit grounded at one point. If the circuit parallels an alternating line, it becomes the secondary of a transformer. In testing this circuit during the day, the ground would be taken off and the circuit opened at the switchboard. While measuring to ground I would frequently get a spark at the jack which could not be attributed to the testing battery. I have sent patrolmen out to find an imaginary cross with live wires, but two or three fruitless searches led me to realize the cause. The accompanying sketch shows this effect on telephone lines. A fire alarm wire, a police telephone line and an arc circuit are on the same cross-arm for a short distance, the fire alarm wire finally leaves the Commission's poles, and later, is carried for some distance on police poles,

thus paralleling a telephone line which also parallels the same or another arc circuit. Ordinarily, the fire alarm wire is a closed low resistance circuit and so acts as the secondary of a transformer of which the arc wire is the primary, and this secondary current induces a tertiary one in the telephone wire which is out of phase with the secondary current induced by the arc current in the same line. This may be obviated by neutralizing the current in the fire alarm wire, although probably the easiest way is a new line of poles.

In paragraph 9 of Mr. Lincoln's paper he speaks of considering two condensers, one between the power wires and the telephone line and the other between the telephone line and ground. I should think the third condenser, that between the power line and ground, should be considered also, for this reason; the first condenser is practically constant, for if there is a variation of potential (especially that caused by leakage) in this condenser, the same variation is caused in the other two, so the relative inductive effect is practically constant; but either of the other two con-



densers will vary from one-half the potential between the power wires to zero. For this reason, I should think the ground wires should be so wired that their condensance can be easily altered or condensers placed at definite places, so they can be varied at will.

The next paper, "The Burning of Wooden Pins on High Tension Transmission Lines," by Mr. C. C. Chesney, was presented by Mr. J. R. Cravath.

At the conclusion of the reading of this paper, Mr. Cravath read discussion which had been presented in New York, by Mr. M. H. Gerry, Jr., H. W. Buck, Mr. Lincoln and Mr. Mershon.

MR. CRAVATH:—It would seem to me that in the first place it is a question of getting an insulator that will not allow enough leakage of current over its surface to burn its pin; or, if you cannot fully accomplish this, of using a construction that will permit of the readiest repair in case the insulator does break down. Of course the use of iron poles in this country is practically out of the question on account of expense, but from the standpoint of quick and easy repair they are excellent. If you

have to renew the insulator only you can do it quickly, but if you have to renew the whole cross-arm or whole pole, it is quite an undertaking. If you use iron pins, of course it is only removing the trouble one step farther away, for then if your insulator leaks the burning occurs somewhere else.

Mention has been made of a line in Mexico which is to use steel towers instead of a wooden pole line. The towers are to be about 440 feet apart, the idea, of course, being to cut down both the cost for poles and the number of insulators. Of course the steel tower line is a much more permanent construction than any wooden pole line could be in the matter of burning, and reduces the number of points at which insulator leakage may occur.

MR. J. R. CRAVATH:—The trouble from burned pins near the sea is sometimes very serious. I happen to know a case where they could not even maintain a 2,000 volt line at times. The mist and fog would blow in and collect on the insulators together with dust, and after a long dry spell when a rain storm came there would be a disheartening number of breakdowns from burning of the pins. They overcame the trouble by putting on some protectors or boxes simply to keep the dust and mist from drifting under the petticoat of the insulator. This box does not come up to the wire or touch the insulator, but rests on the cross-arm and protects the lower part of the insulator from dust.

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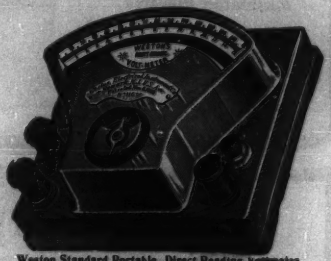

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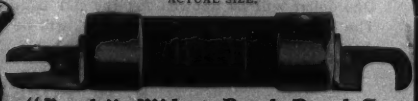

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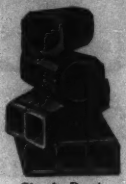

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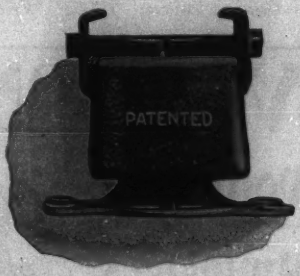

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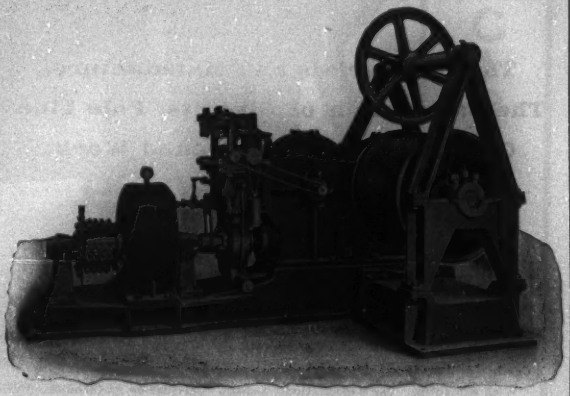

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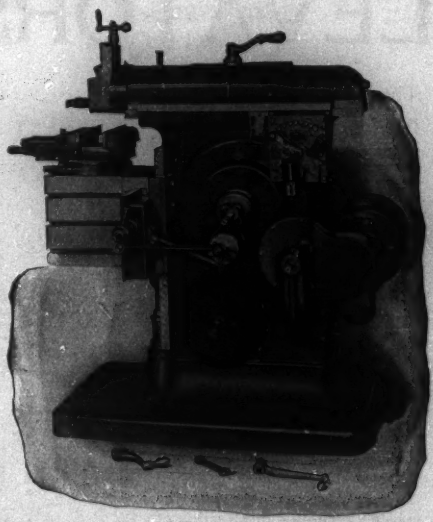

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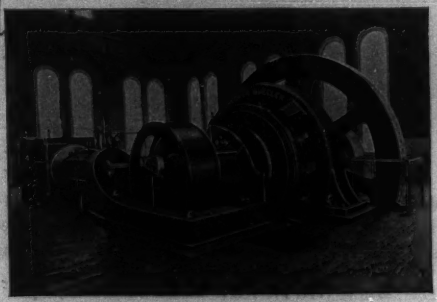

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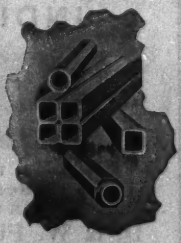

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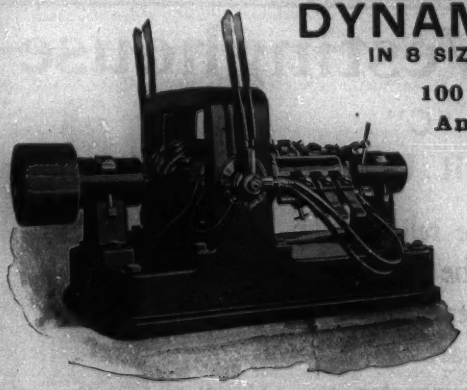

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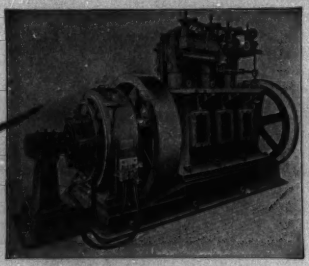

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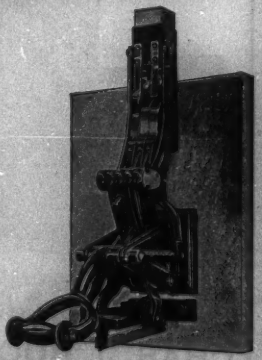

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Application for Admission as Associate.

Extracts from the Constitution, as Amended May 21st, 1901.

MEMBERSHIP

1. The corporate members of the Institute shall be designated as Members and Associates. Members and Associates shall be equally entitled to all of the rights and privileges of the Institute, except eligibility to the offices of President and Vice-President which shall be limited to Members; and Members only shall be entitled to a diploma. There shall also be Honorary Members, who shall be entitled to all the rights and privileges of the Institute, except the right to vote for officers and hold office.

2. A Member shall have been an Associate, and at the time of his transfer to membership, he shall be not less than twenty-seven years of age, and shall be:

a. A Professional Electrical Engineer; or

b. A Professor of Electrical Engineering; or

c. A person who has done important original work of recognized value to electrical science.

3. To be eligible to membership as a professional Electrical Engineer, the applicant shall have been in the active practice of his profession for at least five years; he shall have had responsible charge of work for at least two years, and shall be qualified to design as well as direct electrical engineering works. Graduation from a School of Engineering of recognized standing shall be considered the equivalent of one year's active practice.

4. To be eligible to membership as Professor of Electrical Engineering, the applicant shall have been in responsible charge of a course of Electrical Engineering at a college or technical school of recognized standing, for a period of at least two years.

5. An Associate shall be a person who is interested in or connected with the study or application of electricity.

DUES.

1. The entrance fee, payable on admission to the Institute, shall be five (5) dollars. A fee of ten (10) dollars shall be paid on transfer to the grade of Member, which shall include the fee for a diploma.

2. The annual dues shall be fifteen (15) dollars for members and ten (10) dollars for Associates.

3. The annual dues of Members and Associates residing in foreign countries other than Canada and Mexico, shall be ten (10) and five dollars, (5) respectively.

4. Honorary Members shall be exempt from all payments.

5. Persons elected after six months of the fiscal year have expired, shall pay one-half of the amount of dues for that fiscal year.

6. A Member or Associate in good standing, by the single payment of two hundred (200) dollars in addition to his entrance fee, shall become exempt from all future payments for dues or transfer fee. All money thus paid shall be invested as a permanent fund, of which the interest only shall be subject to appropriation for current expenses

---

To the Board of Directors of the American Institute of Electrical Engineers.

I.....

residing at.....

and at present associated with.....

.....

as.....

do hereby make application for admission into the American Institute of Electrical Engineers, as an **Associate,** with the privilege of subsequent transfer to full membership, should my record prove satisfactory to the Boards of Examiners and of Directors.

Signature and address to which publications and communications should be sent. .....

.....

References if possible to names on the Institute list.

Name of original proposer, through whom application is made. .....

These spaces to be filled in by applicant.

.....

.....

.....

RECORD OF APPLICANT'S ELECTRICAL EXPERIENCE.

1. What is your full name, date, and place of birth?
2. What education, general and technical, have you had; where and how acquired?
3. What is and has been your employment; how long have you been employed in each position referred to?

The undersigned certifies that the above statements are correct and agrees, if elected by the Institute, that he will be governed by the Constitution as long as his connection with it shall continue. He furthermore agrees to promote the objects of the Institute as far as shall be in his power, and in case of his serving his connection therewith that he will return his membership badge, if he has purchased one; provided that for the latter $2.00 shall be refunded.

Signed .....

Date, ... 190

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